

ANNUAL REPORT 2000



HELSINKI UNIVERSITY OF TECHNOLOGY
Low Temperature Laboratory

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LOW TEMPERATURE LABORATORY (LTL)

PREFACE

The international Scientific Advisory Board (SAB) visited the LTL in June 21-22, 2000, and evaluated its scientific program for the second time. The evaluations, started in 1997, are planned to take place every third year. The mission of the SAB is to help the LTL to maintain its status as one of the leading research laboratories in the world by evaluating its current and future research programs and to advise the director in organizational and strategic matters. The Board has especially been asked to find and comment on the weaknesses in the laboratory and its research proposal.

The members of the Board, appointed by Rector Paavo Uronen in 1997, are Prof. Michael Merzenich (UCSF), Prof. Hans Mooij (Delft University of Technology), Prof. Yrjö Neuvo (Nokia Ltd), Prof. Douglas Osheroff (Nobel Laureate, Stanford University), Prof. Stig Stenholm (KTH) and Prof. Semir Zeki (Fellow of Royal Society, University College London). In 2000, the Academy of Finland selected the LTL as one of the 26 national Centers of Excellence. In this connection the Academy appointed two new members into the SAB of the LTL, Prof. Hans Ott (ETH, Zürich) and Prof. Fernando Lopes da Silva (University of Amsterdam). In the board, Profs. da Silva, Merzenich and Zeki are experts in brain research, Prof. Mooij is well known in nanophysics, Profs. Osheroff and Ott in low temperature physics and Prof. Stenholm in theoretical solid state physics. Prof. Neuvo, head of a Nokia research laboratory acts as an expert advisor in applied research matters as well as in academy-industry relations.

The evaluation report, written by Prof. Stenholm, appeared in November (Appendix). According to the report, the LTL continues to excel in the areas of brain research and ultralow low temperature physics. In some aspects of these research areas the Laboratory is virtually without competition. However, mesoscopic physics, which carries great international interest and potential utility, works in an atmosphere of strong competition and rapid development. To survive, the Nanophysics group has to be more aggressive, and more strongly supported both materially and scientifically. A suitable technological niche has to be found, and appropriate theoretical support needs to be organized, in the Laboratory or outside. The Board also noted that further delays in the schedule of the fMRI facility will hamper the development of the brain research program. The LTL has already taken some measures to follow the suggestions of the board: A new 45 m² cleanroom for the Nanophysics group, located on the premises of the LTL, will be commissioned in fall of 2001. Similarly a new building, including 400 m² for the fMRI facility, is under construction and will be ready at the beginning of 2002.

The Brain Research Unit of the LTL helped to organize BIOMAG2000, a major international conference in the neuromagnetism, on the Otaniemi Campus. The Conference, which took place in August, was chaired by Professor Toivo Katila from the Department of Engineering Physics and Mathematics. Academy Professor Riitta Hari served as the chairperson of the Programme Committee and several members of the Brain Research Unit participated in other organizational duties. I would like to thank the organizers for the excellent work done and congratulate them for the successful conference.

Academician Olli Lounasmaa, the founder of the LTL, celebrated his 70th birthday on 20th of August, 2000. The LTL organized on 21st of August a Symposium and a dinner party in his honor. In the Symposium six prominent scientists gave lectures either on physics or on brain research. The speakers were Nobel Laureate Robert Richardson (Olli and the Press: The Importance of Communication about Science to the Public), Academician Alexander Andreev (Highlights of the Finnish Russian Collaboration in Low Temperature Research), Professor, Sir Roger Elliott (Nuclear Magnetism at Positive and Negative Temperatures), Academy Professor Matti Krusius (Forty Years of Low Temperature Research), Academician Teuvo Kohonen (Perspectives on Artificial Networks), and Academy Professor Riitta Hari (Magnetoencephalography – Olli's serious hobby). Over sixty friends and colleagues of Olli attended the dinner party in Kalastajatorppa.

Prof. George Pickett from Lancaster University received on September 8th an honorary doctorate from Helsinki University of Technology. Prof. Pickett, FRS, is a long time friend and frequent visitor of the LTL. He worked in the LTL as a postdoc from 1965 to 1970 and had an essential role in the successful start of the laboratory.

Year 2000 marked also a steady development in the personnel of the LTL. Docent Pertti Hakonen was promoted to full professor of HUT, increasing the number of professors in the LTL to 4. Dr. Nina Forss, M.D., became a docent of experimental neurology at University of Helsinki. University of Helsinki gave also a honorary doctorate in medicine to Academician Olli Lounasmaa. Docent Riitta Salmelin received the international Wiley Young Investigator Award.

Mikko Paalanen

Director of the LTL

SCIENTIFIC ADVISORY BOARD

The Scientific Advisory Board has the following members:

Prof. Fernando Lopes da Silva	University of Amsterdam, The Netherlands
Prof. Michael Merzenich	University of California, San Francisco, USA
Prof. Hans Mooij	Delft University of Technology, The Netherlands
Prof. Yrjö Neuvo	Nokia Ltd, Helsinki, Finland
Prof. Douglas Osheroff (chairman)	Stanford University, California, USA
Prof. Hans Ott	ETH, Zürich, Switzerland
Prof. Stig Stenholm	Royal Institute of Technology, Stockholm, Sweden
Prof. Semir Zeki	University College London, UK

Report of the Evaluation of the Low Temperature Laboratory is enclosed as an Appendix.

PERSONALIA

The number of persons working in the LTL fluctuates constantly since many scientists are employed for relatively short periods only and students often work on part-time basis.

SENIOR RESEARCHERS

Mikko Paalanen, Dr. Tech., Prof., Director of the LTL
Riitta Hari, M.D., Ph.D., Academy Professor, Head of the Brain Research Unit
Peter Berglund, Dr. Tech., Docent, Technical Manager
Marja Holmström, Lic. Phil., Laboratory Administrator
Markus Ahlskog, Dr. Tech.
Flamine Alary, Ph.D.
Harry Alles, Dr. Tech.
Vladimir Eltsov, Ph.D.
Nina Forss, M.D., Ph.D., Docent
Nobuya Fujiki, M.D., Ph.D.
Pertti Hakonen, Dr. Tech., Professor
Päivi Helenius, Dr. Psych.
Matti Hämäläinen, Dr. Tech., Docent
Ole Jensen, Ph.D.
Veikko Jousmäki, Ph.D.
Kirsi Juottonen, M.D., Ph.D., from Apr 1
Tauno Knuutila, Dr. Tech.
Jaakko Koivuniemi, Dr. Tech.
Nikolai Kopnin, Prof.
Matti Krusius, Dr. Tech., Academy Professor
Sari Levänen, Dr. Psych., until May 4

Olli Lounasmaa, Ph.D., Academician
Juha Päällysaho, Ph.D., from Sep 1
Tommi Raji, M.D., Ph.D., until Aug 31
Stephan Salenius, M.D., Ph.D., until Feb 14
Riitta Salmelin, Dr. Tech., Docent
Alexander Sebedash, Ph.D., from Jul 17
Claudia Tesche, Ph.D., Visiting Prof., until July 6
Erkki Thuneberg, Dr. Tech., Docent
Igor Todoschenko, Ph.D., from Jul 11
Juha Tuoriniemi, Dr. Tech.
Simo Vanni, M.D., Ph.D., Jan 1 - 10, May 1 - 31, and Jul 1 - Oct 31
Minna Vihla, M.D., Ph.D.
Grigori Volovik, Ph.D., Visiting Prof.

GRADUATE STUDENTS (SUPERVISORS)

Sari Avikainen, M.D. (Riitta Hari)	Mika Sillanpää, M.Sc. Tech. (Pertti Hakonen)
Rob Blaauwgeers, M.Sc. (Matti Krusius)	Roch Schanen, M. Sc. (Matti Krusius)
Risto Hänninen, M.Sc. Tech. (Erkki Thuneberg)	Mika Seppä, M.Sc. Tech. (Matti Hämäläinen)
Kirsi Juntunen, M.Sc. Tech. (Juha Tuoriniemi)	Teija Silen, M.D. (Nina Forss, Riitta Hari)
Matti Kajola, M.Sc. Tech. (Matti Hämäläinen)	Cristina Simões, M.Sc. Tech. (Riitta Hari)
Juha Kopu, M.Sc. Tech. (Erkki Thuneberg)	Topi Tanskanen, M.Sc. Psych. (Riitta Hari)
René Lindell, M.Sc. Tech. (Pertti Hakonen)	Antti Tarkiainen, M.Sc. Tech. (Riitta Salmelin)
Juha Martikainen, M.Sc. Tech. (Juha Tuoriniemi)	Reeta Tarkiainen, M.Sc. Tech. (Pertti Hakonen)
Lauri Parkkonen, M.Sc. Tech. (Matti Hämäläinen)	Viktor Tsepelin, M.Sc. (Alexei Babkin, Harry Alles)
Jari Penttilä, M.Sc. Tech. (Pertti Hakonen)	Kimmo Uutela, M.Sc. Tech. (Matti Hämäläinen)
Marjatta Pohja, M.D. (Stephan Salenius, Riitta Hari)	Janne Viljas, M.Sc. Tech. (Erkki Thuneberg)
Leif Roschier, M.Sc. Tech (Pertti Hakonen)	Tiina Vuorinen, M.Sc. Tech. (Päivi Helenius, Riitta Salmelin)
Jaakko Ruohio, M.Sc. Tech. (Matti Krusius)	

UNDERGRADUATE STUDENTS

Antti Finne
Samuli Hakala

Riitta Laiho
Vesa Lammela

Maria Husberg	Martin Lehecka
Heikki Junes	René Lindell
Kirsi Juntunen	Sasu Liuhanen
Juha Järveläinen	Juho Peltonen
Jaakko Järvinen	Elias Pentti
Katri Kiviniemi	Paula Routama
Hanna Koivikko	Linda Stenbacka
Noora Kovalainen	Samu Taulu
Jan Kujala	Mervi Valta
Satu Lamminmäki	Janne Viljas

SECRETARIAL AND TECHNICAL PERSONNEL

Teija Halme, secretary	Sami Lehtovuori, technician
Antti Huvila, technician	Mark Mehtonen, assistant until Aug 31
Mia Illman, laboratory nurse	Satu - Anniina Pakarinen, project secretary
Arvi Isomäki, technician	Liisi Pasanen, secretary
Juhani Kaasinen, technician	Kari Rauhanen, technician
Pirjo Kinanen, financial secretary	Antero Salminen, technician
Tuire Koivisto, secretary	Ronny Schreiber, technician
Markku Korhonen, technician	

LONG-TERM VISITORS (More than 4 weeks)

Acad. Alexander Andreev	Kapitza Institute for Physical Problems, Moscow, Russia, Aug 15 - Sep 15
Dr. Sergei Boldarev	Lebedev Physical Institute, Moscow, Russia, Apr 5 - Jun 12, Jun 18 - Oct 30
Dr. Piers Cornelissen	Newcastle University, Newcastle upon Tyne, UK, Jan 4 - 28, Apr 3 - May 2
Prof. Georg Eska	Universität Bayreuth, Germany, Jan 11 - Mar 8
Dr. René Gobbelé	University Hospital Aachen, Department of Neurology, Aachen, Germany, Oct 9 - Dec 1
Dr. Zdenek Janu	Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech, Aug 3 - Nov 2
Mr. Arne Knief	Institute of Experimental Audiology, Biomagnetism Center, Münster, Germany, Jan 8 - Mar 31
Mr. Christian Lammertmann	Institute of Experimental Audiology, Biomagnetism Center, Münster, Germany, Jan 10 - Mar 31, May 13 - 21
Dr. Yung-Yang Lin	Veterans General Hospital, Taipei, Taiwan, Jan 1 - Feb 28
Mr. Alexei Maiorov	Kapitza Institute for Physical Problems, Moscow, Russia, Jul 1 - Aug 31
Prof. Nobuki Murayama	Kumamoto University, Kumamoto, Japan, Jan 1 - Aug 22
Dr. Jyrki Mäkelä	Central Military Hospital, Helsinki, Finland, May 1 - Jun 30

Acad. Alexander Parshin	Kapitza Institute for Physical Problems, Moscow, Russia, Jan 17 - Feb 11, Apr 3 - 23
Dr. Markku Sainio	Finnish Institute of Occupational Health, Helsinki, Finland, part time from Sep 4
Mr. David Schaeffer	Universite Joseph Fourier, Grenoble, France, Mar 15 - Jul 15
Dr. Adriaan Schakel	Freie Universität Berlin, Germany, until Sep 2
Prof. Edouard Sonin	Hebrew University, Jerusalem, Israel, Jan 24 - Feb 23, Jul 19 - Oct 25
Dr. Brigitte Stemmer	Kliniken Schmieder and Lurija Institute, Allenbach, Germany, Aug 28 - Oct 5
Dr. Hideki Yoshida	Tohwa University, Fukuoka, Japan, until Mar 23

SHORT-TERM VISITORS (Less than 4 weeks)

Ms. Jane Aspell	Medical School, University of Newcastle upon Tyne, UK, Jun 20 - Jul 3
Dr. Viatcheslav Avilov	Research Center Rossendorf, Dresden, Germany, Feb 7 - 14
Dr. Anthony Bailey	Institute of Psychiatry, London, UK, Mar 2 - 6, Mar 9 - 13
Prof. Yuri Barash	Lebedev Physical Institute, Russia, Nov 29 - 30
Dr. Erol Basar	Medical University Lübeck, Germany, Mar 25 - 29
Dr. Michael Beauchamp	National Institute of Mental Health, Laboratory of Brain and Cognition, Bethesda, Maryland, USA, Sep 13 - 20
Ms. Katja Biermann	Heinrich-Heine University, Düsseldorf, Germany, Feb 10 - 13
Dr. Sven Braeutigam	The Open University, Milton Keynes, UK, Feb 25 - Mar 5, Mar 10 - 12
Mr. Simone Carozzo	Institute of Neurophysiopatology, University of Genoa, Italy, Mar 27 - 31
Dr. Laila Craighero	University of Parma, Italy, Mar 13 - 31
Dr. Gabriel Curio	Benjamin Franklin Clinic, Berlin, Germany, Mar 13 - 19 and May 25 - 28
Prof. Robert Duncan	University of New Mexico, USA, Oct 13
Sir. Roger Elliot, FRS	Oxford University, UK, Aug 20 - 23
Dr. Luciano Fadiga	University of Parma, Italy, Mar 12 - 31
Dr. Maura Furey	National Institute of Mental Health, Laboratory of Brain and Cognition, Bethesda, Maryland, USA, Sep 12 - 22
Dr. Kurt Gloos	Technische Universität Darmstadt, Germany, Feb 14 - 17
Mr. Joachim Gross	Heinrich-Heine University, Düsseldorf, Germany, May 3 - 13, Aug 8 - 18
Prof. Ramesh Gulrajani	Institute of Biomedical Engineering, Université de Montréal, Canada, Oct 2
Prof. James Haxby	National Institute of Mental Health, Laboratory of Brain and Cognition, Bethesda, Maryland, USA, Sep 12 - 22
Prof. Per Hedegård	Niels Bohr Institute for Astronomy, Physics and Geophysics, Copenhagen, Denmark, Apr 11 - 14
Prof. Frank Hekking	Universite Joseph Fourier, Grenoble, France, Mar 5 - 12

- Dr. Anya Hurlbert University of Newcastle, Newcastle upon Tyne, UK, Mar 5 - 12, Jun 20 - 30
- Dr. Reyer Jochemsen Leiden University, The Netherlands, Jan 14 - 26, Sep 20 - Oct 5
- Acad. George Kharadze E. Andronikashvili Institute of Physics, Georgian Academy of Sciences, Tbilisi, Georgia, May 4 - 18
- Dr. Erika Kirveskari Helsinki University Central Hospital, Finland, Oct 1-15
- Prof. Takafumi Kita Hokkaido University, Sapporo, Japan, Jun 13 - 16
- Prof. Vladimir Kravtsov International Centre for Theoretical Physics, Trieste, Italy, Nov 20 - 26
- Dr. Reinhard König Physikalisches Institut, Universität Bayreuth, Germany, Feb 21 - 27
- Dr. Kim Lefmann Risø National Laboratory, Roskilde, Denmark, Mar 3 - 9, Apr 11 - 17
- Dr. Ulf Leonhardt KTH Stockholm, Sweden, Mar 20 - 21
- Prof. Bernd Lütkenhöner Institute of Experimental Audiology, Münster, Germany, Mar 3 - 6, May 15 - 21
- Dr. Livio Narici University of Rome (Tor Vergata), Italy, Mar 27 - 31, Jul 24 - Aug 21
- Prof. Christo Pantev Institute of Experimental Audiology, Biomagnetism Center, Münster, Germany, Jan 9 - 15
- Dr. Marco Peresson Fatebenefratelli "S. Pietro" Hospital, Department of Neurology, Rome, Italy, Aug 7 - 20
- Dr. Michele Piana INFN Università di Genova, Italy, Mar 27 - 30, Aug 1 - 8
- Prof. George Pickett, FRS Lancaster University, UK, Aug 19 - 23
- Prof. Massimo Riani University of Genoa, Italy, Mar 27 - 30
- Prof. Robert Richardson Cornell University, Ithaca, USA, Aug 17 - 24
- Prof. Walter Sannita Center for Neuroactive Drugs, University of Genoa, University Hospital, Genoa, Italy, Mar 27 - 31
- Dr. Martin Schürmann Medical University of Lübeck, Germany, Mar 2 - 31, May 26 - Jun 9
- Mr. Michael Schulte Institute of Experimental Audiology, University of Münster, Germany, Mar 25 - 31
- Dr. Jens Siewert University of Catania, Italy, Mar 22 - 26
- Dr. Mohamed Larbi Soltani University of Annaba, Laboratory of Magnetism and Spectroscopy of Solids, Annaba, Algeria, Jul 19 - 21
- Director Michael Steiner Hahn-Meitner Institute, Berlin, Germany, Aug 21 - 23
- Dr. John Stins The Open University, Milton Keynes, UK, Feb 25 - 27
- Prof. Stephen Swithenby The Open University, Milton Keynes, UK, Mar 10 - 13
- Dr. George Tvalashvili Lancaster University, UK, May 14 - 29
- Dr. Jimenez Rene Urbina Commissariat à l'Energie Atomique DRECAM/SPEC, Gif-sur-Yvette, France, Mar 30 - Apr 2
- Prof. William Vinen, FRS University of Birmingham, UK, Jan 10 - 17
- Dr. Taeko Wydell Brunel University and University College London, Department of Human Sciences, London, UK, May 10 - 20, Dec 1 - 10
- Prof. Yasumasa Takano University of Florida, Gainesville, USA, Nov 22 - 25

Dr. Victor Yakovenko

University of Maryland, College Park, USA, Jun 15 - 17

Dr. Andrei Zaikin

Forschungszentrum Karlsruhe, Germany, Sep 18 - 23

GROUP VISITS

A Delegation from the Finnish Academy, Feb 10

Secretary General Anneli Pauli

Ms. Maaria Lehtinen

Ms. Ulla Ruotsalainen

Ms. Ulla Malkamäki

25 secondary school students from Pori SYL, Feb 11

A Delegation from EESTEC students exchange, mainly foreign graduate students, Feb 15

A Delegation from the synchrotron radiation group, graduate students mainly from Oulu and Turku, Mar 9

Scientists from newly elected Polish Centers of Excellence, Mar 21

Prof. Dr. Krzysztof Zieliński, Academy of Mining and Metallurgy, Cracow

Prof. Dr. Marian Noga, Academy of Mining and Metallurgy, Cracow

Prof. Dr. Janusz M. Rosiak, Technical University of Lodz

Dr.med. C. Peszyński-Drewno, Technical University of Lodz

Prof. Dr. Jacek Gulifski, Adam Mickiewicz University, Poznan

Prof. Włodzimierz Stafczyk, Polish Academy of Sciences, Lodz

Prof. Dr. Jacek Kuźnicki, Polish Academy of Sciences, Warsaw

Prof. Ewa Urbafska, Medical University School, Lublin

Prof. Dr. Lech Dietrich, Polish Academy of Sciences, Warsaw

Dr. Janusz J. Bucki, Warsaw University of Technology

Director Jerzy A. Gąsiorowski, State Committee for Scientific Research

Vice Director Jacek Mazur, State Committee for Scientific Research

Prof. Eino Tunkelo, Finnish Academy of Technical Sciences

25 engineers from YLE, May 15

A Delegation from Taiwan, NSC-AOF Meeting on Low Temperature Physics, May 24 and 26

Prof. H.-C. Ku, National Tsing Hua University

Mrs. I.-F. Ho, National Science Council

Prof. H.Z. Chan, Suh-Teh College of T&C

Y.Y. Chen, Academia Sinica

Prof. C.M. Fu, National Kaohsiung Normal University

Prof. Y.S. Gou, National Chaio-Tung University

Prof. S.Y. Hsua, National Chaio-Tung University

Prof. J.Y. Juang, National Chaio-Tung University

Prof. H.C. Kao, Tamkang University

Prof. J.J. Lin, National Chaio-Tung University

Prof. J.B. Shi, Feng Chia University

Prof. K.H. Wu, National Chaio-Tung University

Prof. H.D. Yang, National Sun Yat-Sen University

Prof. T.J. Yang, National Chaio-Tung University

Prof. T.R. Yang, National Taiwan Normal University

Secretary Isabelle Chen, Taipei Representative Office, Belgium
Doc. Simo Jaakkola, University of Turku
Prof. Jukka Pekola, University of Jyväskylä

LTL Scientific Advisory Board, Jun 21-22

Prof. Fernando Lopes da Silva, University of Amsterdam, The Netherlands
Prof. Michael Merzenich, University of California, San Francisco, USA
Prof. Hans Mooij, Delft University of Technology, The Netherlands
Prof. Yrjö Neuvo, Nokia Ltd, Finland
Prof. Douglas Osheroff, Stanford University, California, USA
Prof. Hans Ott, ETH, Zürich, Switzerland
Prof. Stig Stenholm, Royal Institute of Technology, Stockholm, Sweden
Prof. Semir Zeki, University College London, UK
Scientific Secretary Jaana Aalto, Academy of Finland
Secretary General Anneli Pauli, Academy of Finland
Scientific Secretary Tuula Pitkänen, Academy of Finland
Technology Expert Juha Tanskanen, Tekes, Finland
Rector Paavo Uronen, Helsinki University of Technology

A delegation (55 people) from JETRO (Japan External Trade Organization) High-Tech Mission to Finland, Sep 25

First year physics students and their parents (75 participants) took a guided tour to the LTL, Oct 28

LOW TEMPERATURE PHYSICS RESEARCH

NANOPHYSICS RESEARCH

M. Ahlsgog, **P. Hakonen**, R. Lindell, M. Martin, M. Paalanen, J. Penttilä, L. Roschier, P. Routama, M. Sillanpää, E. Sonin, R. Tarkiainen

The unexplored territory of mesoscopic physics lies at the crossroads of ballistic and diffusive phase-coherent electron motion supplemented by the competition between Coulomb and superconducting correlations. In fact, quantum mechanical objects at mesoscopic level present one of the most intriguing topics of present-day physics. How well quantum mechanical principles can be exploited as the system size grows? This problem is one of the major hurdles on the road towards solid state quantum computation. All these questions can be addressed in our studies of superconducting nanocircuits at low temperatures. Similar phenomena are encountered also in our studies of carbon nanotubes which provide examples of clean molecular conductors. Here the interest is strengthened by the fascinating physical description of a nanotube as a strongly interacting Luttinger liquid. Several fundamental physical questions have to be clarified before the full potential of nanotubes as a building blocks of various new nanoelectronic devices can be properly evaluated.

Single Josephson junctions

Macroscopic quantum phenomena can be well investigated in single Josephson junctions. We started our work with Cooper pair tunneling under the influence of Coulomb blockade, and investigated how this can be tuned using Ohmic dissipation. This led to the observation of a superconductor/insulator (SI) transition in single junctions, efficiently decoupled from the environment. Our

experiments revealed a transition between superconducting and insulating behavior as a function of E_J/E_C , the ratio of Coulomb blockade and Josephson coupling energy, when the shunt resistance became smaller than about 6.5 k Ω . Recently, we have extended our work into energy level spectroscopy in order to investigate directly the energy bands, the presence of which is fundamental *e.g.* for appearance of the SI-transition.

For the energy level spectroscopy, we have developed a new type of detector which is based on inelastic Cooper pair tunneling in a mesoscopic superconducting junction. This scheme is based on the theory of phase fluctuations, according to which the Coulomb blockade in a single superconducting tunnel junction is strongly affected by the environment. Non-coherent Cooper pair tunneling is allowed only if energy is exchanged with the surroundings. Thus, inelastic Cooper pair tunneling provides a good tool for observing all kinds of environmental modes, *i.e.* transitions between energy levels, in a rather simple fashion.

Using the developed energy level spectroscopy, we have been able to verify the quantum mechanical band picture of a Josephson junction in its full form. We have determined the energies of the levels as well as obtained evidence of the band widths of delocalized states in the cosine-potential of the Josephson coupling. Our results can be well described by the relevant Schrödinger equation, *i.e.* the Mathieu equation, which shows how a Josephson junction evolves from a single harmonic oscillator in the classical limit into a periodic system with energy bands as the Josephson energy is tuned. Evolution of the system as a function of E_J/E_C was traced in the range $E_J/E_C = 7-14$ in good agreement with the predictions based on the Mathieu equation.

Superconductor/normal metal interfaces

The penetration of normal correlations to an adjacent superconductor and the extension of superconducting pairing amplitudes into the normal metal across a clean metallic S/N interface displays a wealth of intricate phenomena. We have studied the electronic density of states in mesoscopic superconductors near a transparent interface with either non-magnetic normal metal or a ferromagnetic metal. In our tunnel spectroscopy experiment, a substantial density of states is observed at sub-gap energies close to a ferromagnet. This effect of smearing of the superconductor density of states is weak in the case of non-magnetic metal. Comparison of our data with calculations based on the Usadel equations yields a relatively good agreement for the ferromagnetic case, but the weak influence of non-magnetic metal is inconsistent with the theoretical predictions.

Radio-frequency SETs

Modeling of noise properties of a SET, read using rf-reflection measurements, has been continued, partly in collaboration with the group of Robert Schoelkopf at Yale. The influence of matching on noise properties has been investigated in detail. In principle, the noise performance of a true rf-SET (a single electron box connected to a high-Q tank circuit) is better than that of a standard double junction SET read using reflection techniques. To show this experimentally we have investigated niobium strip line resonators, produced at the State Research Center (Espoo). In the frequency range 1 – 6 GHz, we achieved a Q-value of 1200.

Nanotubes and nanotube devices

Carbon nanotubes, both single walled (SWNT) and multiwalled (MWNT), provide unique building blocks for molecular nanoelectronics. For example, they can be employed as islands with quantized charge in SETs. Since the self-capacitance of such a nanotube is about 10 - 20 aF/ μm , rather long sections can be used to make islands for SETs and the island capacitance remains still quite small.

Most of our recent effort has been concentrated on the problem of noise in nanotubes, both in the regime of single electron tunneling and beyond. We have tried to reduce the total amount of fluctuations by special free-standing sample design (see below). In addition, we believe that the variation of noise with frequency (single fluctuator noise) can be used to characterize interlayer coupling in MWNTs.

In one of our devices we employed two crossing MWNTs to construct a three terminal device. The lower nanotube, with gold contacts at both ends, acted as the central island of a single electron transistor while the upper one could be functioned as a gate electrode owing to the large intertube tunneling resistance of 1 G Ω . Coulomb oscillations with single period were observed; *i.e.* van der Waals forces caused by the upper tube did not split the lower one in two sections. The voltage noise of this nanotube in the SET regime was gain and current dependent. The charge sensitivity at 10 Hz was $6 \cdot 10^{-4}$ e/Hz which is similar to values reported for standard lithographic devices. The current dependence of the noise points towards unknown resistance fluctuations in the nanotube itself.

The only known way to reduce $1/f$ -noise in SETs is to avoid contact of the central island with any dielectric material. In our best devices, this is achieved by using a free-standing nanotube as an island. Manipulation with an atomic force microscope is employed to move the desired multiwalled carbon nanotube (MWNT) on top of two adjacent gold electrodes. The contact resistance can be lowered to about 10-20 k Ω by treating the ready-made sample in vacuum at 700 C for 30 sec. The $1/f$ -noise of such a carefully manufactured device, $6 \cdot 10^{-6}$ e/Hz at 45 Hz, rivals the performance of the best metallic SETs of today.

Luttinger Liquid model versus Quantum Fluctuations of the Environment

The theory based on environmental quantum fluctuations (EQF) has been very successful in explaining the Coulomb blockade of normal tunnel junctions in detail (J. Penttilä et al, Phys. Rev. B **61**, 10890 (2000)). According to this theory, linear dissipative environment close to a single junction leads to specific power laws ($dI/dV \propto V^\alpha$) for the tunnelling conductance at small voltages. In fact, these power laws are indistinguishable from those obtained for the Luttinger liquid (LL) with a strong Coulombic interaction. At higher voltages, however, the predictions of the EQF-theory and the LL-model deviate significantly from each other.

We have analyzed our results on good-quality, arc-discharge-grown MWNTs using both the standard Luttinger-liquid formulas as well as the environmental analysis of Coulomb blockade in single tunnel junctions. At small voltages we do not find any difference between the power laws of these two formulations. At large voltages, however, we find that only the quantum environment theory is applicable. The environmental analysis yields for the transmission line impedance at high frequencies $Z = \sqrt{L/C} = 1.3-7.7$ k Ω , while the power law exponents $\alpha = 0.25 \pm 0.05$ at small bias. From these two determinations we obtain for the kinetic inductance $L_{\text{kin}} \sim 1$ nH/ μm , over three orders of

magnitude larger values than typical geometric inductances. Due to large values of inductance, carbon nanotubes provide an excellent high-impedance environment for normal junctions at large frequencies, which is crucial for single-electronics phenomena.

New equipment and facilities

During the previous year we purchased a wire bonder: Delvotek 5430. Design and construction of an in-house clean room was started. The room will be operational in June 2001. In addition, a new dilution refrigerator equipped with a 12 Tesla magnet was ordered. This machine is designed to facilitate low-noise measurements in the GHz range.

HELIUM MIXTURES AND NUCLEAR MAGNETISM IN METALS (YKI PROJECT)

K. Juntunen, T. Knuutila, J. Martikainen, E. Pentti, A. Sebedash, **J. Tuoriniemi**

By the turn of the year, the experiment on nuclear magnetism in pure rhodium metal was carried to the end. Tauno Knuutila defended his thesis about the subject and in this context we announced to the public the final estimate for the lowest achieved temperature of rhodium nuclei, about 100 pK – the new world record of low temperatures.

At the first quarter of the year 2000, the construction of the $^3\text{He}/^4\text{He}$ -mixture cell for the new experiment was finalized. The copper nuclear coolant with the pre-tested vibrating-wire resonators in the silver sintered cavities was packed into a multi-cell structure joined by an intermediate filling capillary. Once mounted into the cryostat, a cold leak in the cell and an incapability of the heat-exchanger cold plate of our dilution refrigerator of absorbing the heat due to the cell-filling lines slowed us down somewhat, but satisfactory operation of the nuclear demagnetization stage of the mixture cell was achieved by the end of the year.

The experiments on $^3\text{He}/^4\text{He}$ mixtures were started by a relatively dilute concentration of 1.7 %, at about which the theoretical studies indicate the highest probability for *s*-wave pairing of ^3He atoms. Although the predicted transition temperatures vary by several orders of magnitude, various models agree fairly well upon the concentration dependence of the pairing tendency. The experiment will proceed in a natural way by adding more ^3He until the maximum solubility of about 9.5 % is reached. Up to some 6.5 % we may work at the saturated vapor pressure, and above that the cell must be pressurized up to about 10 bar. Even if we make only two demagnetizations at each concentration, the experiment proceeds at a rate of about two to three months per solution.

The only indicator of the state of the helium mixture in our cell is obtained through the use of vibrating-wire resonators. Since this experiment is very susceptible to even extremely small heating, we designed a detection scheme based on a dc SQUID. This way we obtained an outstanding signal to noise ratio at excitation levels so small, that the heat input is negligible even for this application.

We also set forward the collaboration with Kapitza institute in Moscow to build another experimental cell based on a novel method of cooling $^3\text{He}/^4\text{He}$ mixtures by adiabatic melting of solid ^4He . The method utilizes self-cooling in the liquid and thereby completely eliminates the enormous Kapitza barrier between the liquid and any external refrigerant. The cooling occurs due to the absorbed heat of mixing, when the ^3He component dissolves to ^4He once the ^4He crystal is allowed to

melt. The design of the cell is basically ready and the construction of the thermal and pressure elements is on their way. The former nuclear stage of our refrigerator, used for the rhodium experiment, will be employed for pre-cooling the ^3He component below its superfluid transition temperature prior to adiabatic melting of ^4He .

The work on nuclear magnets was continued by theoretical studies of the rhodium-spin system in collaboration with Risø National Laboratory, and by preparations of a new set of experiments on lithium metal. Lithium is considered highly interesting due to its anticipated superconductivity at millikelvin temperatures – to date it has been cooled down to about 4 mK elsewhere. As a nuclear magnet Li is a system dominated by fairly strong dipolar-interaction and very well suited for nuclear demagnetization cooling. The practical difficulties with this material are due to its high reactivity, so that the sample must be encapsulated in a suitable way. The experiments, at least the search for superconductivity of Li, can be run in parallel with the adiabatic-melting experiment owing to the enormous cooling capacity of our copper-nuclear stage in the temperature range 0.1 – 1 mK.

TOPOLOGICAL OBJECTS IN QUANTUM FLUIDS (ROTA PROJECT)

R. Blaauwgeers, S. Boldarev, V. Eltsov, G. Eska, Z. Janu, **M. Krusius**, V. Lammela, P. Routama, J. Ruohio, A. Schakel, and R. Schanen

Such many-body systems of condensed matter, where free-particle motion is possible at the lowest temperatures, have superfluid or superconducting ground states. They are commonly known as macroscopic quantum systems. Examples are superfluids, superconductors, and atomic Bose-Einstein condensates. These many-body states with coherent free particle motion are described by an order parameter which is analogous to a macroscopic Schrödinger-like wave function. The order-parameter field displays coherence over length scales which are a characteristic property of the system, but may include spatially dependent structure due to textures and the presence of topologically stable defects. Many of the defect structures may also involve a quantized quantity, like the vortex line with macroscopic quantized circulation, which makes the order parameter distribution in the bulk analogous to a quantum field. Experimentally the system, in which the largest variety of defects have been identified, is superfluid ^3He . During the past year, our efforts have been concentrated on creating an interpretation on the measurements from previous years and on preparing for new a experiment.

Dynamically driven topological transitions in $^3\text{He-A}$

Quantized vortex lines are formed as a response to an external field: in superconductors it is the externally applied magnetic field while in superfluids, Bose-Einstein condensates, and possibly in neutron stars this happens as a response to rotation. In the anisotropic A phase of superfluid ^3He there exists an other alternative: instead of vortex lines to create sheets with quantized vorticity. Whether lines or sheets are formed has now been found to depend on how the rotation is applied: If it varies sufficiently rapidly and strongly, then vortex sheets appear and displace vortex lines. This happens because sheets adapt to changes in rotation faster, which means that such a state relaxes more rapidly towards the instantaneous equilibrium density of superfluid circulation. Vortex sheets have been suggested to exist in other anisotropic quantum systems, such as unconventional

superconductors with anisotropic order parameters, and this opens the possibility that sheets, and not lines, could be a common response of all such systems to rapidly changing external fields.

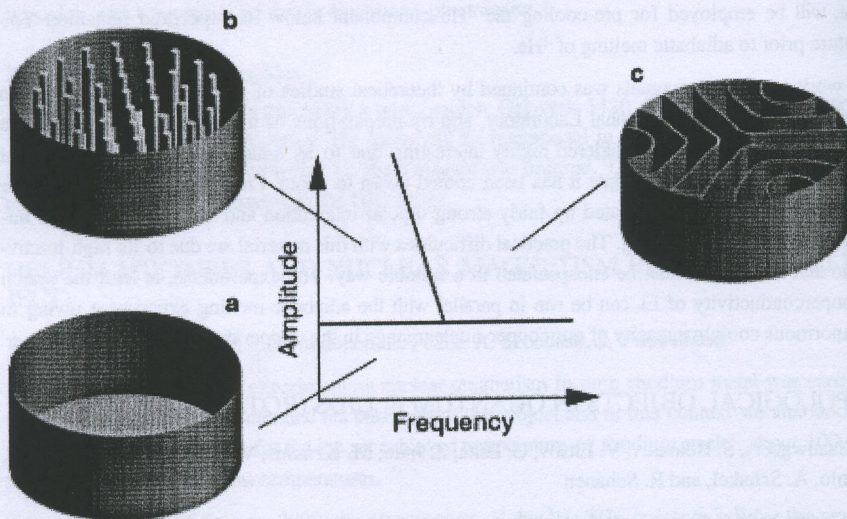


Fig. 1. Different states of a cylindrical sample in an axially oriented external field. The relevant field for superfluids is rotation of the sample, while for superconductors it is the applied magnetic field. The different states are generated (and are either stable or metastable) as a function of the amplitude and frequency of the periodic external field, as shown in the diagramme. (a) The vortex-free Meissner state exists at low fields below a critical value: Here the superfluid remains at rest and the superconductor expels the magnetic field. (b) When the field is slowly increased then the state with quantized vortex lines is created. Here supercurrents circulate around linear vortex cores. This allows the superfluid to participate in rotation and the magnetic field to penetrate into the superconductor. (c) If the field is rapidly alternating then in superfluid $^3\text{He-A}$ vortex sheets are created. In this state supercurrents flow along multiple planes which are predominantly oriented along the radius of the container. If the modulation of the external field is switched off and the velocity is kept constant, then the state with sheets persists since it is topologically stable.

In an isotropic superfluid a vortex sheet is unstable with respect to break-up into individual vortex lines. In $^3\text{He-A}$ the vortex sheet is formed from a domain-wall-like soliton sheet, into which vortex lines are confined. This structure arises as a natural consequence from the anisotropy of the A-phase order-parameter field and its preference for continuity on the small length scale of the superfluid coherence length ξ . The equilibrium state of the vortex sheet can be adiabatically grown in slowly increasing rotation from a pre-existing seed of soliton sheet. It is known to form as one continuously meandering surface. For several years the dynamic properties of the vortex sheet have remained a puzzle. It has been known, for instance, that the seed for growing the equilibrium vortex sheet can be created in rapid back and forth rotation, but also that the dynamic response of the continuous equilibrium sheet is slow. We have now shown that the vortex sheet can appear in topologically different configurations which can be distinguished according to their dynamic responses.

As opposed to the slow continuous sheet much faster dynamics is achieved with a large number of separate sheets which all are connected at both ends to the cylindrical wall and which are oriented as much as possible radially in the container. This greatly facilitates the motion of circulation quanta which in rapidly varying motion predominantly occurs radially into or out of the container. Vorticity enters or leaves the sheet at the two connection lines where it is attached to the side wall of the rotating container. At the wall connection within the sheet the order parameter is already distorted and the critical velocity for creating new vorticity is minimized. Moreover, the motion of vorticity is anisotropic, being an order of magnitude faster along the sheet than perpendicular. This means that multiple radially oriented sheets have much faster dynamic response than one continuously folded long sheet or, in fact, faster than separated vortex lines. In the experiments a spontaneous transition from lines to sheets is observed when the drive frequency is increased. This is the first example in any quantum system that the temporal properties of the external field determine the topological structure of the dynamic response. So far quantized vorticity in the form of a vortex sheet has only been observed in $^3\text{He-A}$ and only in this laboratory.

Interaction of defects with the interface between $^3\text{He-A}$ and $^3\text{He-B}$

How do objects of different topology, structure, and quantization interact? This can be studied at the interface which separates the A and B phases and across which the phase of the order-parameter is continuous. What happens when a doubly-quantized A-phase vortex line with continuous order-parameter structure meets a transverse A-B interface? Does a mechanism exist by which these vortex lines may connect with the singly-quantized B-phase vortex lines with non-singular vortex core structure? In the two phases both the quantization of the vortex lines and their structural length scales are very different.

Measurements have previously been performed in which the A-B interface travels at some adjustable velocity through the container which is rotating at a constant angular velocity. In the presence of the moving boundary the A and B-phase vortices have been found to avoid each other. The moving interface tends to sweep the vortices of the retreating phase to the walls of the container for annihilation. A new experiment has now been designed and constructed where the AB phase boundary can be maintained at a fixed stable position transverse to the rotation axis. The rotation velocity can then be varied independently. By measuring separately the NMR signals from the A and B phases above and below the interface, it is possible to investigate what the critical velocities are in the two phases and to conclude whether and how vortices connect across the interface. At present no other system exists where these basic questions can be studied in such detail. In the new set up a number of other measurements can also be performed, such as the changes in these properties as a function of the velocity of the A-B interface. This question becomes important in the Early Universe where a number of phase transitions must have swept through the rapidly expanding and cooling system after the Big Bang. Our experiment started to operate in its planned form in the beginning of 2001.

Nb thin-film LC resonators

Our NMR measurements are performed in the continuous wave regime using as sensor an LC resonator with a high quality factor Q . At low frequencies (up to several MHz) the inductive and

capacitive elements are spatially separated and can be assembled from discrete components, i.e. from a coil wound from superconducting wire and a high-Q capacitor. With a parallel-coupled LC resonator Q values up to 10^5 have been reached at temperatures below 0.1 K. In principle a more efficient geometry for the measurements could be a planar Nb thin-film resonator where the inductively coupled sample is sandwiched between two thin-film devices. We have experimented with sputtered Nb thin-film LC resonators which were fabricated at the VTT Microelectronics Centre. They have been tested in the temperature range 0.05 – 1 K in magnetic fields up to 30 mT. Their Q value increases with decreasing temperature proportional to $1/T$ and reaches 10^3 at 0.05 K. As a function of magnetic field Q turned out to be unstable and to display large noise-like disturbances which, however, are reproducible from one field sweep to the next. These instabilities are attributed to dielectric losses in the plasma deposited SiO_2 insulation layer, since a thin-film Nb coil alone reaches a Q value of up to 10^5 at 0.05 K. Improvements to the quality of the insulation layer are under investigation.

^3He - ^4He dilution refrigerator

The $T \rightarrow 0$ limit (in practice $T \sim 0.10 T_c$) has not been investigated in rotating experiments. To explore the structure and dynamics of quantized vorticity in the collisionless regime of quasiparticle scattering, the measuring range from our present low temperature limit of approximately $0.3T_c$ in the B phase and $0.5T_c$ in the A phase should be extended down to $0.10T_c$. For this our present precooling refrigerator, a ^3He - ^4He circulating dilution refrigerator, will be replaced with a new unit which has been constructed in the Laboratory by Dr. Sergey Boldarev. The new refrigerator insert has now been completed and leak tested. The operational tests will be started in the spring of 2001. It is expected that the machine should reach low precooling temperatures of less than 10 mK and provide an improved platform for the nuclear stage, to achieve stable ^3He temperatures in the 0.1 – $0.2T_c$ regime.

INTERFACES IN QUANTUM SYSTEMS

H. Alles, A. Babkin, J. Heiskala, J. Härme, R. Jochemsen, H. Junes, R. Luusalo, J.-S. Lönnroth, A. Maiorov, A. Parshin, I. Todoschenko, V. Tsepelin

In equilibrium, the surface of a crystal can be either smooth (faceted) or rough (rounded) according to its crystallographic orientation and temperature. It is expected that at low temperature the equilibrium crystal shape should show many different types of facets which are surrounded by rough areas. As temperature rises the facets should disappear at so called roughening transition temperatures. Each type of facets has its own transition temperature.

In ordinary crystals it is extremely difficult to observe the equilibrium shape of crystals because the relaxation times are simply too long. Therefore experiments have been made with microcrystals, *i.e.*, crystallites with a characteristic size of the order or less than $1 \mu\text{m}$. As a result, some facets and roughening transitions with mostly low Miller indices have been observed.

The superfluid/solid interface of helium which exist at low temperatures and high pressures allows studies on the equilibrium shape of quite macroscopic crystals. In helium crystals, however, due to the weak coupling of the interface to the solid lattice, the size of equilibrium facets is expected to be very small. This has been probably one of the reasons why only three different types of facets have

been observed so far both in ^4He and ^3He . On the other hand, it is well known that as faceted areas grow slower than rough areas the facets with much larger than the equilibrium size can be observed during growth of the crystals.

In order to study morphology and growth kinetics of *bcc* - ^3He crystals we have built a Fabry-Pérot type of interferometer into our nuclear demagnetization cryostat. In our scheme all optical components are inside the 4-K vacuum can with an exception of a He-Ne laser located at room temperature. The operating temperature of the interferometer is close to 10 mK, which makes it probably the coldest multiple-beam interferometer ever made. The vertical resolution in the interface position is a few μm while the horizontal resolution of about 15 μm is limited by the pixel size of the slow-scan CCD camera.

With our novel optical setup we have completed our first set of experiments which were carried out mainly at our lowest temperature of 0.55 mK. Several original results were obtained. First of all, we discovered eight new types of facets on growing ^3He crystals. In addition we have been able to measure the growth rates of almost all observed facets. Assuming spiral growth mechanism the step energies for the different facets can be calculated from our data.

Our experimental results prove that at higher temperatures in ^3He there are at least eleven roughening transitions which is by far more than in any other known system. According to theoretical estimations these transitions should all fall to the temperature range well above 2.5 mK where liquid ^3He is in a normal state and there is a large latent heat of crystallization. Due to these reasons it is very difficult to control the dynamics of ^3He crystals in this temperature range and to observe an equilibrium roughening transition in ^3He . However, by observing the shape of growing crystals at these relatively high temperatures one can certainly find the lower limits of the roughening transition temperatures for different types of facets. So far in ^3He only one type of facets, (110), has been studied with that purpose.

THEORY OF SUPERFLUID ^3He

A. Andreev, R. Hänninen, N. Kopnin, J. Kopu, E. Sonin, **T. Thuneberg**, J. Viljas, **G. Volovik**

The majority of theoretical work in the LTL is closely connected to the experimental effort in the laboratory. Only a few of the ongoing theoretical projects are listed below.

$^3\text{He-A}$ is very exceptional superfluid because there is a good chance of understanding quantitatively the critical velocity of vortex formation. The reason is that vortex formation arises from an instability of the local anisotropy axis \mathbf{l} , and this happens in the bulk because \mathbf{l} is fixed at surfaces, and thus surface roughness is not important. We have studied the critical velocity in parallel plate geometry using a two-dimensional model. We find that the critical velocity for vortex lines depends only weakly on the plate separation D , but if there is initially a soliton defect, the critical velocity depends essentially on D . The latter case is closely related to the growth of the vortex sheet, and it explains semi-quantitatively the observed dependence on the angular velocity.

We have studied the effect of surface singularities in superfluid $^3\text{He-A}$. Using the Ginzburg-Landau theory we find a reduced critical velocity in the presence of an \mathbf{l} singularity. We plan to extend these calculations to wider channels using an adaptive grid in the numerical calculations.

The Josephson coupling between two reservoirs of superfluid ^3He has been studied in the University of California at Berkeley. They found a new type of current-phase relation at low temperatures, so-called " π -state". While it seems clear that this effect arises from the 3×3 matrix form of the order parameter in ^3He , the details are still poorly understood. We have continued our previous studies by concentrating on pinhole models of the Josephson junction. We find that there are two different explanations for the π -state. The pros and cons of both models have been analyzed but it seems that more experimental data is needed to finally judge between the two.

By numerical and analytical studies of the time-dependent Ginzburg-Landau (TDGL) model we show that vortex nucleation in superfluid ^3He by rapid thermal quench in the presence of superflow is dominated by a transverse instability of the moving normal-superfluid interface. The instability threshold is found analytically as a function of supercurrent density and the front velocity. The dynamics of vortex evolution at long times after the quench is investigated.

We have also performed studies on vortices in other superfluid Fermi systems such as superconductors. We have derived a general quasiclassical approach for long-range magnetic field quantization effects in superconductors. The method is applied to superclean d-wave superconductors in the mixed state for delocalized excitations. We show that transitions between the different quantum can be observed experimentally due to resonance in the a.c. vortex friction.

We have reviewed the basic ideas and results on the vortex dynamics in clean superfluid Fermi systems. The forces acting on moving vortices are discussed including the problem of the transverse force which was a matter of confusion for quite a time. Finally, we formulate the equations of the vortex dynamics including all the forces and the inertial term associated with excitations bound to the moving vortex.

New laser manipulated Bose condensates have multicomponent order parameter and some of them are similar to the superfluid ^3He . We have suggested how to create exotic vortices in a vector and spinor Bose condensates, including the half-quantum vortex which is analogous to the cosmic Alice string.

The momentum-space topology in $3+1$ and $2+1$ space-time has proved to be a useful tool for investigation of the most important properties of a strongly correlated fermionic systems. For $3+1$ systems the important universality class is determined by topologically stable Fermi points in momentum space. In the extreme limit of low energy, the condensed matter system of this universality class acquires all the symmetries which we know today in high energy physics: Lorentz invariance, gauge invariance, general covariance, etc. The chiral fermions, as well as gauge bosons and gravity field arise as fermionic and bosonic collective modes of the system. This introduces a conceptual similarity between condensed matter and the quantum vacuum of Standard Model, which also contains the Fermi point. For a $2+1$ fermionic systems the momentum-space topology gives rise to the quantization of different physical parameters, such as Hall conductivity and spin-Hall conductivity, and to quantum phase transitions with the abrupt change of the momentum-space topology. In particular, the combined p-space and r-space topology determines the topology of the energy spectrum of fermion zero modes living within the topological defects: fermionic charges of the topologically nontrivial extended objects, axial anomaly, etc.

We have continued an investigation of the event horizons, which can be simulated in condensed matter. An unusual physical behaviour of the quasiparticle horizon is found, which is caused by

non-Lorentz invariant modifications of the effective space-time experienced by the quasiparticles ("matter") at high momenta. By introducing a "relativistic" conserved energy-momentum tensor, we derive quasi-equilibrium states of the fluid across the "Landau" quasiparticle horizon at temperatures well above the quantum Hawking temperature. Nonlinear dispersion of the quasiparticle energy spectrum is instrumental for quasiparticle communication and exchange across the horizon. It is responsible for the establishment of local thermal equilibrium across the horizon, with the Tolman temperature being inhomogeneous behind the horizon. The inhomogeneity causes relaxation of the quasi-equilibrium states due to scattering of thermal quasiparticles, which finally leads to a shrinking black hole horizon. This process serves as the classical thermal counterpart of the quantum effect of Hawking radiation and will allow for an observation of the properties of the horizon at temperatures well above the Hawking one.

CERN - COLLABORATIONS

P. Berglund, J. Koivuniemi

The collaboration of LTL with CERN started 30 years ago when Tapio Niinikoski constructed the first dilution refrigerator for polarized targets. The collaboration was activated in 1990 when the Spin Muon Collaboration, SMC, needed a dilution refrigerator and CERN, because of financial restrictions, was not able to maintain a polarized target group of its own. The SMC dilution refrigerator is the largest dilution refrigerator in the world with a maximum circulation of 300 mmol/s.

During 2000 the LTL has been active in 2 collaborations: COMPASS and RD39. COMPASS is a continuation of SMC and RD39 is a separate smaller silicon detector project. COMPASS has 29 and RD39 15 collaborating institutes.

All our activities at CERN have been participation in cryogenic hardware design and construction. Some parts have been manufactured in the workshop of the LTL. It has also required participation in actual measurements at CERN when the experiments have been carried out.

COMPASS

Common Muon Proton Apparatus for Structure and Spectroscopy

<http://wwwcompass.cern.ch/> (COMPASS)

COMPASS is a high-energy physics experiment under construction at the Super Proton Synchrotron (SPS). The purpose of this experiment is to study hadron structure and hadron spectroscopy with high intensity muon and hadron beams.

After confirmation of the original EMC result by experiments at CERN and SLAC, it is now firmly established that the spin content of the nucleon is not entirely due to quark spins. Competing explanations exist for this result. COMPASS has a rich spin physics programme which can be completed in a running time of four years. First answers can be obtained already after about two years. These estimates are based on a one-year measurement with a proton target and on 18 month measurement with a deuteron target. The two target materials are needed to separate helicity distributions of different quark flavours.

The RD39 collaboration

<http://rd39.web.cern.ch/RD39/>

Silicon strips and pixels are the detectors chosen for front line tracking applications in particle physics. After an initial research on superconducting microstrips, which had a negative outcome, the collaboration underwent a fairly substantial reorganization a couple of years ago and now focuses on silicon detectors in cryogenic environment. In 1998, a spectacular recovery of the charge collection efficiency was observed in heavily irradiated silicon detectors when they were cooled to cryogenic temperatures.

The RD39 cryostat and some of the data acquisition instruments have been built in collaboration between LTL and CERN.

BRAIN RESEARCH UNIT

Senior members: N. Forss, **R. Hari**, P. Helenius, M. Hämäläinen, V. Jousmäki, K. Juottonen, S. Levänen, O.V. Lounasmaa, J. Mäkelä, J. Päälysaho, M. Sainio, S. Salenius, R. Salmelin, C. Tesche, S. Vanni, M. Vihla

Foreign postdocs: F. Alary (Toulouse), N. Fujiki (Kyoto), O. Jensen (Copenhagen), Y.Y. Lin (Taipei), N. Murayama (Kumamoto), H. Yoshida (Fukuoka)

NEURO-BIRCH & other visitors

F. Alary (Toulouse), J. Aspell (Newcastle upon Tyne), A. Bailey (MRC-P), E. Basar (Lübeck), M. Beauchamp (Bethesda), S. Braeutigam (Milton Keynes), S. Carozzo (Genoa), L. Craighero (Parma), G. Curio (Berlin), L. Fadiga (Parma), M. Furey (Bethesda), R. Gobbele (Aachen), J. Haxby (Bethesda), A. Hulbert (Newcastle upon Tyne), A. Knief (Münster), C. Lammertmann (Münster), Y.-Y. Lin (Taipei), B. Lütkenhöner (Münster), N. Murayama (Kumamoto City), L. Narici (Rome), C. Pantev (Münster), M. Peresson (Rome), M. Piana (Genoa), M. Riani (Genoa), W. Sannita (Genoa), M. Schürmann (Lübeck), M. Schulte (Münster), C. Simões (Lisbon), B. Stemmer (Konstanz), J. Stins (Milton Keynes), S. Swithenby (Milton Keynes), W. Woods (Newcastle upon Tyne), T. Wydel (Brunel)

Functions of the human cerebral cortex have been studied by measuring magnetic fields outside the head. The magnetoencephalographic (MEG) method allows totally non-invasive studies of healthy and diseased human brains during different tasks and conditions. Our 306-channel neuromagnetometer (Vectorview, Neuromag Ltd), used since 1998, houses 204 gradiometers and 102 magnetometers with a whole-scalp coverage. To combine functional and structural information, we typically integrate MEG data with the subject's magnetic resonance images (MRIs). Since 1994, an important part of the research has been done in collaboration with European scientists visiting the laboratory through the Neuro-BIRCH (Biomagnetic Research Center in Helsinki) Large-Scale Facility, financed by the European Union. The third funding period of the Large-Scale Facility (Neuro-BIRCH III) started in April 2000 and will continue for another 3 years.

Sensorimotor functions

F. Alary, J. Aspell, M. Beauchamp, P. Brown, G. Curio, N. Forss, J. Haxby, N. Fujiki, M. Furey, R. Hari, A. Hurlbert, M. Illman, V. Jousmäki, K. Juottonen, J. Kilner, A. Knief, H. Koivikko, R. Laiho, C. Lammertmann, M. Lehecka, R. Lemon, S. Levänen, Y.-Y. Lin, B. Lütkenhöher, N. Murayama, J. Mäkelä, L. Narici, J. Numminen, C. Pantev, L. Parkkonen, M. Pohja, J. Päällysaho, T. Raji, K. Saarela, M. Sainio, S. Salenius, R. Salmelin, R. Schreiber, M. Schürmann, T. Silen, C. Simões, L. Stenbacka, T. Tanskanen, S. Vanni

Auditory system

Dyslexia

Developmental dyslexia is often associated with problems in phonological processing based on or accompanied by deficits in perception of rapid auditory changes. We have previously shown that dyslexics perceive a directional hearing illusion in an abnormal manner and they are also impaired in perceiving pitch streaming. To further elucidate the underlying sensory problems, we have been running MEG experiments on adult dyslexics who listen to various sound sequences.

Noise/square-wave stimuli, used to mimic fricative consonant/vowel transitions, elicited both onset responses and responses to the changes within the stimuli. The change-responses were dampened in dyslexic subjects, in agreement with their difficulties in feature detection during speech-sound processing. In an oddball paradigm, magnetic mismatch fields were diminished in dyslexic subjects, especially in the left hemisphere, suggesting a deficiency in their preattentive auditory processing. A study with pairs of noise bursts (stimulus onset asynchronies from 70 to 500 ms) attributed the sluggish auditory processing of dyslexics to difficulty in switching attention.

The magnocellular deficit theory assumes that several small deficits observed in dyslexic subjects reflect dysfunction of fast-conducting "magnocells" which exist in different parts of the brain. Hearing as a warning sense relies on rapidly conducting fibers, and we thus wondered whether auditory alerting would be distorted in dyslexic adults. We quantified sound-induced spinal facilitation by measuring the amplitudes of H-reflex, a monosynaptic spinal reflex, after loud sounds that preceded the reflex by various intervals. The audiospinal facilitation was of normal strength in dyslexic adults, indicating normal auditory alerting via rapidly conducting cerebrospinal pathways. The observed slightly prolonged facilitation could be related to the dyslexics' general sluggishness of sensorimotor processing.

Binaural hearing

In normal hearing, sounds activate our brains through two ears, and the inputs from each ear reach the auditory cortices of both hemispheres. The resulting binaural cortical responses are thus a mixture of inputs from both ears and it has not been able to find out which part of responses to binaural sounds derives from either ear. We have solved this problem by labeling the auditory inputs from both ears by "frequency-tagging": Continuous 1-kHz tones, presented either monaurally to left or right ear, or binaurally were amplitude modulated (left-ear tone at 26.1 Hz and the right-ear tone at 20.1 Hz). Both hemisphere and ear-specific information was obtained on binaural interaction by analyzing the cortical MEG signals both in frequency and time domain.

In the left hemisphere, responses to ipsilateral sounds were significantly suppressed during binaural presentation, whereas responses to contralateral tones were not significantly affected. Thus the left hemisphere's preference to right-ear input was strongly accentuated during binaural hearing, possibly providing the neuronal basis for the well-known "right-ear advantage" in right-handed subjects during dichotic listening. In the right hemisphere, the responses were significantly and similarly suppressed for both contralateral and ipsilateral sounds. Thus this first noninvasive analysis of contributions of the two ears to binaural cortical responses indicates that the inputs from the two ears compete strongly in the human auditory cortex but with clear hemispheric differences.

Somatosensory system

Our previous MEG studies have shown that the human SII cortex responds to both contra- and ipsilateral stimulation and that bilateral integration of tactile input from the two hands seems to be an important feature of the human SII cortex. Therefore, we aimed to quantify to which extent representations of different fingers of the two hands overlap in the somatosensory cortices. Tactile stimuli were delivered to the right index finger interspersed by stimuli presented to the other fingers of the same or of the other hand. The results indicate a very strong and symmetric overlap of representations of the fingers of both hands in the SII cortices of both hemispheres, and a weaker functional overlap of the finger representations of the same hand in the SI cortex.

Many previous studies have also suggested hemispheric differences in the activation strength of SII cortices; in healthy subjects median nerve stimuli activate more strongly the left than the right SII cortex, regardless to the side of stimulation. We have now started to study whether this difference would be related to handedness. Preliminary results suggest that the SII is cortex is activated more strongly in the left than the right hemisphere both in right- and left-handed subjects, although individual variation is larger in left-handeds.

To compare the functional properties of neurons at SI and SII cortices, we recorded transient vs. sustained fields to stimulus trains delivered to the median nerve at 8-12 Hz. The SI and SII cortices responded strikingly differently to stimulus trains: whereas SI followed each stimulus with a sharp transient response up to at least 12 Hz, the transient responses were much less prominent at SII which mainly responded with an sustained field that returned to baselevel at 800-1000 ms. The different response patterns of SI and SII suggest that the inhibition following the early excitatory responses is weaker at SII than SI, or that inhibitory responses of these two areas differ in their relative timing.

High-frequency (600 Hz) oscillations are known to be superimposed on the N20m response of the SI cortex. These oscillations are supposed to reflect rapidly repeating population spikes in thalamocortical afferents and/or intracortical neurons. We found that the signal-to-noise ratios (SNRs) of these bursts were higher for magnetometers (SNR = 17) than for gradiometers (SNR = 12). Optimised noise reduction increased the SNR of the best magnetometer channel to 25. Thus, in this experimental setting magnetometers clearly outperformed gradiometers in terms of SNR. The exceedingly high SNR revealed a complex, non-stationary burst field pattern indicating that multiple and/or moving sources are contributing to these spike-like SEF components.

We have recently designed and constructed a new mechanical device to study proprioceptive processing in the human cortex. This air-pressure-operated, totally nonmagnetic device can be used to

passively move fingers and toes at modifiable extents, speeds, and envelopes. MEG experiments using passive index finger movements have just been started.

To reveal functional relevance of the previously demonstrated vibration-induced auditory-cortex activation in congenitally deaf subjects, we studied the tactile accuracy of congenitally deaf and normal hearing subjects in frequency discrimination and in detection of sudden suprathreshold frequency changes in a monotonous sequence of vibratory stimuli. We found that congenital deafness can enhance the accuracy of suprathreshold tactile change detection while tactile frequency discrimination is not significantly changed, although there is a clear trend towards a reduced threshold. Two post-lingually deafened subjects had a slightly enhanced tactile sensitivity compared with the average performance of the hearing group. In addition, their MEG responses later than 60 ms after vibrotactile stimuli were more distributed than in the hearing subjects, and seemed to include various superior temporal areas but not supratemporal auditory areas. It thus seems that the functional reorganization of the primary sensory areas can only follow very early sensory deprivation.

We have recently demonstrated a novel 7-9 Hz *sigma* rhythm arising from the parietal operculum area, possibly from the SII cortex. Our first evidence of a possible SII rhythm derived from somatosensory evoked fields to single median nerve stimuli, illustrating clear oscillations after the main evoked responses in the over the SII region. Spectra of spontaneous activity recorded at rest showed topographically distinct maxima of 7-9 Hz activity close to the SII cortex. In addition, in three subjects source locations of the spontaneous 7-9 Hz oscillations could be reliably determined and they agreed with SII activation. Finally, the rhythm could be entrained by 4-12 Hz stimulus trains, with maximum entrainment when stimuli were presented at the rhythm's intrinsic frequency. Our data therefore suggest the existence of a 7-9 Hz *sigma* rhythm in the human SII cortex that can be spatially discriminated from the sources of the sensorimotor mu and the auditory tau rhythms.

We have found abnormal activation of the somatosensory cortical network in patients with Unverricht-Lundborg type (ULD) progressive myoclonus epilepsy. Giant responses at SI apparently indicated hyperexcitability, ipsilateral SI responses abnormal callosal conduction (probably related to higher risk for generalized seizures), and absent SII responses may reflect deficient bilateral tactile integration and/or sensorimotor integration. As the next step, we are going to investigate the relationship between genotype and neurophysiological phenotype of healthy carriers of the gene mutation.

Pain

Several previous imaging studies have shown that cortical areas that are activated to nociceptive stimuli are also part of the somatosensory cortical network that processes innocuous tactile input. Furthermore, many patients with chronic pain report changes in tactile sensitivity of the affected area. We have started to clarify how chronic pain affects central processing of tactile input. So far we have recorded, in co-operation with ORTON hospital, responses to electric median nerve stimuli and purely tactile finger stimulation from six females suffering from complex regional pain syndrome (CRPS) and from six healthy age matched control subjects. We have also started in co-operation with the Department of Neurosurgery, Helsinki University Central Hospital, to study somatosensory and motor processing in patients with chronic pain before and after placement of neurostimulator to epidural space.

Motor functions

Cortex-muscle coherence

We have previously found that rhythmic ~20-Hz (and during strong contraction 40-Hz) activity, generated in the primary motor cortex, is coherent with motor unit firing of isometrically contracting muscle. The delays between cortex and different muscles agree with the corresponding cortex-muscle conduction times. Both 20- and 40-Hz cortical rhythms thus seem to drive motor unit firing in contracting muscles.

We investigated task-dependent modulation of the cortex-muscle coherence during precision grip tasks while subjects used index finger and thumb to grip two levers that were under robotic control. Subjects received visual feedback of lever force levels and were instructed to keep them within target boxes throughout each trial. Coherence was significantly smaller when the task was performed under an isometric condition (levers fixed) compared with a compliant condition in which subjects moved the levers against a spring-like load. Furthermore, there was a positive, significant relationship between the level of coherence and the degree of lever compliance. These results argue in favor of coherence between cortex and muscle being related to specific parameters of hand motor function.

We have also used the cortex-muscle coherence as a tool to unravel cortical representation of trunk muscles while the subjects contracted either the long abdominal muscles (ABD) or the paraspinal muscles in the back (PS) isometrically. Significant but rather weak cortex-muscle coherences were found for both muscles. The coherent cortical activity was clearly contralateral for PS but bilateral for ABD. The observed sites of cortical representations for the trunk muscles agree with the motor homunculus of Penfield. These measurements were technically much more demanding than studies of cortex-limb coherences because of ECG- and respiration-related noise in the EMG recordings and the difficulties of the subjects to voluntarily control abdominal and back muscles. The low magnitudes of the coherence values may also be explained by the relatively small size of the cortical representation of the trunk muscles.

In an ongoing study we are examining cortex-muscle coherence in patients with cerebellar infarcts. The preliminary results suggest that the normal cortex-muscle coherence depends on the integrity of the cerebello-cortical circuits, but the type of abnormality strongly depends on the location of the cerebellar lesion.

In a genetically homogeneous group of patients with ULD-type progressive myoclonus epilepsy, cortex-muscle coherence occurred at ~17 Hz vs. ~20 Hz in controls, and the strengths of the dominant coherent peaks were 2-4 fold compared with the control group. Whereas the coherence was strictly contralateral in controls, additional coherent activity was observed ipsilaterally in five out of eight patients. The pathologically increased MEG-EMG coherence in ULD patients may reflect reduced inhibition in the motor cortex and/or altered cerebello-thalamo-cortical output that may contribute to disturbed control of voluntary movements.

Reactivity of the motor cortex

We have used the reactivity of the ~20 Hz component of the human mu rhythm as a tool to study the functional state of the primary motor cortex. In patients suffering from ULD progressive myoclonus epilepsy the motor cortex rhythm was on average 5 Hz lower and the strength double com-

pared with controls. In controls, median nerve stimuli elicited a small transient decrease, followed by a strong increase ("rebound") of the ~ 20 -Hz level. In contrast, the patients showed no significant rebounds of the rhythm. As the ~ 20 -Hz rebounds apparently reflect increased cortical inhibition, our results indicate that peripheral stimuli excite motor cortex for prolonged periods in ULD.

Using similar methods, we have started to investigate how activation of the motor and sensory cortices are modified in patients suffering from restless legs syndrome. This syndrome is characterized by periodic dysesthesias at rest, which are relieved by moving dysesthetic limbs. Dopaminergic and GABAergic medication reduce symptoms. Previous transcranial magnetic stimulation studies have suggested reduced intracortical inhibition. Patients will be studied both with and without medication.

Neural basis of visual perception and vision-related brain activation

Proper understanding of processes underlying visual perception requires information on the activation order of distinct brain areas. We measured dynamics of cortical signals with MEG while subjects viewed stimuli at four visual quadrants. Activation emerged 55-70 ms after stimulus onset both in the primary posterior visual areas and in the anteromedial part of the cuneus. Other cortical areas were active after this initial dual activation. The anteromedial cuneus apparently either comprises a homologue of the monkey area V6 or is an area unique to humans. Our results show that visual stimuli activate two cortical areas right from the beginning of the cortical response. The anteromedial cuneus has the temporal position needed to interact with the primary visual cortex V1 and thereby to modify information transferred via V1 to extrastriate cortices.

It is known from psychophysical measurements that detection reaction times (RTs) to sinusoidal gratings prolong as a function of spatial frequency (sf). On the other hand, the latencies of neuro-magnetic steady-state responses have been shown to increase at the same rate. Our aim was to search for possible cortical correlates of the RT increment by recording VEFs to Gabor patches of different spatial frequencies (0.5, 2.0, 7.0, 11.5 and 14.0 c/deg). We found rather similar increment rates of the RTs and of the activation peak latencies at the ventral occipital cortex as a function of sf; the findings render that area a possible cortical correlate for the reaction time delay.

Another recent study searched for cortical correlates of the so-called Pufriicht phenomenon. When a swinging pendulum or a dynamic random dot pattern is viewed with a light-attenuating filter before one eye, the pendulum bob or the dots on the pattern are perceived to move in an elliptical path in depth. The perceived motion in depth depends on the density of the filter used and the eye covered with the filter. If the right eye is covered, the motion appears counterclockwise and if the left eye is covered the motion appears to be clockwise. Up to now, very little is still known about the time coding of this phenomenon and where in the visual system this information is processed. Our MEG recordings have revealed distinct regions (with precise time coding) of the human visual system, involved in processing the spatiotemporal phase disparity information necessary to perceive the Pufriicht phenomenon.

Recently we have characterised human brain activity that correlates with global coherent visual motion perception while the observers passively viewed motion sequences of sparse random dot fields. Neural activity in the human MT+ complex varied with the strength of unidirectional coherent motion.

Functional magnetic resonance imaging (fMRI) data have shown that visually presented categories of objects elicit distinct spatial activation patterns in ventral extrastriate cortex, and that these category-related responses can be modulated by attention. We aimed to study the temporal course of the attention in collaboration with scientists from NIH, Bethesda. Subjects performed a one-back recognition task of faces or houses, either from normal photographs or from double exposure images of superimposed faces and houses. The results indicate that the earliest components of the temporally specific neural responses to faces and houses in ventral extrastriate cortex are not modulated by attention, whereas the later components are. The shift to attention-modulated responses occurred 200-250 ms after stimulus onset.

In a simulation study several partly overlapping sources were placed into various visual cortices, to correspond physiologically reasonable activation patterns. Ten members of the research team analyzed these data blindly, both with time-varying multi-dipole models and with the L1 minimum-current estimate. The results are under analysis.

In collaboration with visiting scientists from Parma we are continuing studies on visuospatial selective attention, using a modified "Posner paradigm". One aim is to reveal whether human frontal eye fields are activated during selective visuospatial attention, and to study the related temporal sequence of activation in the frontoparietal network.

To study mechanisms of residual vision in patients with cortical blindness, we have measured (in collaboration with Department of Physiology, University of Helsinki and Brain Work Laboratory, Institute of Occupational Health), visual evoked fields in a patient with right posterior cerebral lesion and left visual field hemianopia. His vision had partially recovered with intensive training before our measurements. Compared with the processing in the healthy side, early occipital responses were attenuated for both passive viewing of checkerboard reversal patterns and a letter identification task. In both conditions there were prominent longer-latency responses at the right superior temporal cortex. We suggest that the activation in the superior temporal cortex can partially compensate for the failure to produce synchronized population responses at the early stages of visual cortical processing.

Multisensory interactions

In daily life, we often process stimuli of more than one sensory modality at the same time. Audio-visual interactions have been studied extensively whereas audiotactile interactions, present for example when we explore with fingers some textures, are much less well known. We have recently run two series of MEG experiments to find out brain sites and cortical temporal dynamics of audiotactile interaction. Preliminary results suggest two sites and times of interaction: one early interaction in the superior parietal lobe and a later one close to the second somatosensory cortex.

When trained musicians read musical score, they may hear the corresponding sounds, even complex ones, in their mind's ear. To trigger such auditory images by visual stimuli, we presented musicians with visual notes and instructed them to imagine the corresponding sounds. In three control conditions, we asked subjects (i) to look at dots resembling the notes (but without stafflines), (ii) to listen to sounds corresponding to the notes, and (iii) to attend to faces shown as infrequent stimuli among frequent visual notes. Minimum current estimate analysis showed brain activations specific to the imagery task in the midline parietal cortex (precuneus) within 110 ms after the note, and a spread of activation to temporal and frontal areas within the next 70 ms. These data imply a tempo-

rospatial activation sequence of multiple brain areas (among them auditory association areas) involved when musicians learn and recall firmly established audiovisual associations.

Action viewing

S. Avikainen, N. Forss, **R. Hari**, J. Järveläinen, S. Levänen, S. Liuhanen, N. Nishitani, K. Uutela

As social creatures, we humans spend a considerable part of our waking time in predicting the intentions and feelings of our cocitizens. This largely unconscious cerebral computing is based on sensory cues derived from other persons' behavior, gestures, and vocalizations. The reading of other persons' intentions, often called the 'theory of mind', seems to be a continuum, with autism as the most dramatic example of a total lack of the mindreading skill.

The monkey brain has been shown to contain an observation/excecution matching system which may play an important role in action understanding and imitation: 'mirror neurons' of the premotor cortex discharge both when the monkey performs hand actions and when it observes another individual to make similar actions. We have earlier demonstrated that the human brain also contains a mirror-neuron system (MNS), involving at least the Broca's region and the primary motor cortices.

The preferred stimuli for the monkey mirror neuron system are goal-directed hand movements and orofacial gestures. We recently studied whether the human mirror-neuron system would also be activated during observation and on-line imitation of still pictures of orofacial gestures. When subjects were observing or imitating lip forms, the cortical activation progressed dynamically from the occipital cortex to the STS regions, to the inferior parietal lobules, and to the inferior frontal lobes of both hemispheres, and then 70-100 ms later to the primary motor cortices of each hemisphere. As in the previous study [10], the signals were strongest during imitation. Thus even still pictures of lip forms activate an extended cortical network of the human mirror-neuron system in a well defined temporal order.

When deaf and normal-hearing subjects passively viewed sign language, rather similar brain areas were activated in both groups. Activity was stronger in the right STS region and the left dorsal premotor cortex for deaf signers than for normal hearing non-signers, probably related to sign language comprehension. On the other hand, the right superior parietal lobule was more strongly activated in hearing non-signers, apparently reflecting visuomotor encoding of complex and unfamiliar movement sequences. This study illustrates that not only object-directed movements but also other hand gestures can activate the human mirror-neuron system.

Since the representations of self-generated and observed actions overlap in the mirror-neuron system at least to some extent, one may well ask how subjects can preserve the sense of self in such conditions. Most probably, matching of the motion-related activity and proprioceptive feedback is needed for the distinction of mirror-neuron system activations resulting from the subject's own intentions vs. from viewing other persons' actions. Therefore it is interesting that we recently observed that both the primary and the secondary somatosensory cortices show behavior similar to the mirror neuron areas: Manipulation a small object with fingers and observation of a similar movement had parallel effect on the SI and SII cortices: The SI signals were increased and SII signals decreased in all situations, except when the right manipulating hand was stimulated. These results suggest involvement of the somatosensory cortices in the human mirror neuron system.

We are now studying how the human MNS would be activated by observation and on-line imitation of hand postures. In the first study, Japanese volunteers who did not know American nor Japanese Sign Languages (ASL and JSL) and Japanese deaf-mutes who did not know ASL but were fluent in JSL were asked to observe and imitate different hand postures of JSL or ASL. Cortical activations progressed dynamically from the occipital area to the posterior middle temporal, superior temporal (STS), inferior parietal, posteroinferior frontal (Broca) and primary motor (M1) areas of both hemispheres. During all tasks, the strongest activations occurred at STSs of both hemispheres. For JSL hand postures, Broca and M1 activations were stronger in the left than the right hemisphere, but vice versa for ASL. These results indicate functional hemispheric differences in the cortical dynamics of the mirror neuron system during observation and imitation of hand postures. In an ongoing study we are studying the effects of normal vs. abnormal finger postures on the MNS activation, as well as the effort in the observed movement (for example walking vs. running).

We have also started to run both behavioral imitation and MEG experiments on subjects with Asberger syndrome, a mild autistic disorder. As autistic subjects are deficient in their imitation skills, we hypothesized that they might have abnormalities in their action observation/execution system.

Language perception and production - function and dysfunction

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Auditory processing of speech and non-speech sounds was assessed in two experiments. In one study we compared change detection for natural vowels (deviant: /a/ or /e/; standard: /i/) and for sounds consisting of two pure tones that represented the two lowest formant frequencies of these vowels. Our aim was to see whether spectral changes in successive stimuli are detected differently for speech and non-speech sounds. As expected, mismatch field (MMF) amplitudes for the complex tones directly reflected acoustic deviation: the amplitudes were stronger for the complex tones representing /a/ than /e/ formants, *i.e.*, when the spectral difference between standards and deviants was larger. In contrast, MMF amplitudes for the vowels were similar despite their different spectral composition, whereas the MMF onset time was longer for /e/ than /a/. Thus the degree of spectral difference between standards and deviants was reflected by the MMF amplitude for the non-speech sounds and by the MMF latency for the vowels.

In the other study, we mapped cortical auditory processing in dyslexia. Sensitivity to the phonological structure of spoken words is a prerequisite for reading acquisition. Indeed, reading-impaired individuals often have problems in processing and manipulating speech sounds. We characterized auditory cortical activation evoked by spoken sentences, bisyllabic pseudowords, complex non-speech sound pairs and simple tones. A robust and replicable difference between dyslexic and non-reading-impaired individuals was seen in the left supratemporal auditory cortex 100 ms after speech onset. This N100m response was abnormally strong in dyslexic individuals for words presented in a sentence context and for the naturally produced pseudowords. For the complex non-speech sounds and simple tones the N100m response amplitudes were similar in dyslexic and non-impaired individuals. We are currently investigating which features of speech (or non-speech stimuli) are critical for eliciting the abnormally strong N100m response in dyslexic individuals, *i.e.*, whether the abnormal N100m response is associated with impaired phonological processing.

In the visual domain, we have continued to elucidate the cortical dynamics of early perceptual processing. To complement our earlier study on letter-string reading, we now investigated cortical responses to another special category of images, namely faces. Our stimuli consisted of faces and objects, both drawn and photographed. Some of the drawn faces were masked with variable levels of noise. The first activation pattern, seen at 100 ms after image onset in the occipital area, was in every respect similar to the one measured in the letter-string study. The activation strength correlated strongly with the complexity of images and, accordingly, seems to be related to low-level visual feature analysis. The second activation pattern emerged at about 150 ms after image onset in the inferior occipito-temporal cortex bilaterally. The response was strong to faces, but clearly weaker to objects and to faces rendered unrecognizable by high levels of noise. We had detected similar specificity for letter-strings in the same time window. However, the letter-string specific sources were relatively strongly lateralized to the left inferior occipito-temporal cortex. The activation pattern at 150 ms probably represents object-based analysis, with distinct neuronal populations tuned to process image categories for which fast and accurate recognition is needed.

We have initiated investigations on cortical correlates of language function in aphasic subjects. Neural correlates of success and failure in picture naming were studied in three aphasics, classified as post-semantic anomics. In these patients, cortical magnetic activity predicted whether they would name the pictures correctly, produce a semantically related but incorrect name, or whether they would give no answer. The effects in MEG responses were seen well before overt vocalization in the posterior regions of the brain, reported to be linked to semantic and/or phonological processing. Although all the three patients were behaviourally classified as relatively similar post-semantic anomics, and our stimuli were chosen to reflect a breakdown at post-semantic processes, the cortical dynamics preceding success or failure in naming varied remarkably across patients. Naming disorders which are neuropsychologically similar at the surface may thus vary drastically in their neuro-functional basis.

Further, we have demonstrated a neurofunctional basis for double dissociation of verb and noun production in aphasic naming. The same 100 carefully selected line drawings were used as stimuli in both tasks. In healthy subjects, the activation sequence was similar for action and object naming. However, in an anomic patient with superior naming of verbs compared with nouns, stronger responses were found to object than action naming in three cortical areas (Broca's area, left middle temporal cortex, and left superior parietal cortex), whereas activation of the left inferior parietal cortex was stronger for action than object naming. The altered pattern of activations may reflect an attempt to compensate for the failure of the original, fluent naming network.

To facilitate MEG analysis of continuous language tasks, where fixed trigger times are difficult or even meaningless to identify, we have developed an analysis and visualization tool for description of cortico-cortical interaction strengths and interareal delays in non-averaged MEG data. For example, stuttering occurs during self-initiated speech production and reading but is dramatically diminished by any kind of external pacing. Thus, the usual MEG paradigms are far from optimal for studying this elusive phenomenon. Testing of the new analysis method in characterization of cortical networks during continuous reading in stutterers and fluent speakers is currently starting.

Development of clinical applications of MEG in collaboration with HUCH

N. Forss, R. Hari, M. Hämäläinen, M. Illman, K. Juottonen, E. Kirveskari, J. Mäkelä, S. Salenius, R. Salmelin, and M. Seppä

A 'CliniMEG' team was assembled in 1997 to develop clinical applications of MEG to routine use in collaboration with the Department of Clinical Neurosciences at the Helsinki University Central Hospital. The focus has been on preoperative evaluation of patients with brain tumors and epilepsy. We have developed routine methods to provide the neurosurgeon with 3-dimensional visualization of the functional anatomy of the rolandic cortex, to facilitate tumor resection without damaging functionally irretrievable areas in the somatomotor strip. The central sulcus has been identified by functional and morphological criteria; the functional landmarks were based on somatosensory responses to hand, foot, and occasionally also to lip stimulation, and motor cortex identification on cortex-muscle coherence. The functional locations are displayed on 3-D reconstructions of the individual brains, with the blood vessels, derived from MR angiography, shown on the exposed brain surface; this was achieved with software developed at the LTL specifically for this purpose.

In 2000 CliniMEG continued to study patients with brain tumors and epilepsy for presurgical purposes; the hospital and the patients have not been charged for the examinations. During surgery, the preoperative localizations have been confirmed with cortical stimulations and recordings, and at least one member of the CliniMEG team has been present in the operation room. The preoperative visualization of the functional anatomy has greatly facilitated navigation during the neurosurgical operation. Some of the routines developed in BRU have already been transferred for clinical use in HUCH (Dept. of clinical neurophysiology).

Methodological development

J. Gross, S. Hakala, M. Husberg, **R. Hari, M. Hämäläinen, O. Jensen, V. Jousmäki, M. Kajola, J. Kujala, J. Numminen, L. Parkkonen, R. Salmelin, M. Seppä, A. Tarkiainen, S. Taulu, K. Uutela, and R. Vigario**

Our activities consist of improving the hardware for neuromagnetic measurements and development of new acquisition and analysis software.

Instrumentation

The collaboration with VTT Automation to study the noise performance of the new magnetically shielded room and to adjust the active noise compensation system to reject external noise has continued. The Vectorview MEG system has been maintained in close collaboration with Neuromag Ltd.

Continuous head position monitoring

Methods for measuring the head position during MEG data acquisition and algorithms for correcting the source analysis using the measured movements were developed. Simulations and a pilot study showed that the head position can be measured accurately also during the data acquisition without interfering the MEG signals and that the effect of head movements can be compensated for by adjusting the forward calculation.

Dynamic imaging of coherent sources

Functional connectivity between cortical areas may appear as correlated time behaviour of neural activity. Coherence between signals of MEG/EEG sensors covering different scalp areas is commonly taken as a measure of functional coupling. However, this approach provides vague information of the actual cortical areas involved, owing to the complex relation between the active brain areas and the sensor recordings. We have developed an analysis tool for estimating coherences between cortical areas. Dynamic imaging of coherent sources (DICS) uses a spatial filter to localize coherent brain regions and provides time courses of their activity. Reference points for the computation of neural coupling may be based on brain areas with maximum power or other physiologically meaningful information, or they may be estimated starting from MEG sensor coherences. The performance of DICS was illustrated with simulated data and recordings of spontaneous activity in a healthy subject and in a Parkinsonian patient.

Minimum current estimate

The software for calculating minimum current estimates (MCEs) was improved and the use of a beamformer technique for extracting the activity of a selected brain area was implemented.

The calculation of grand averages of MCE data was taken into use. The co-registration between subject and the standard brain was achieved by using the elastic deformation software developed for the Brain Atlas project.

Evaluation of realistic conductor models

The advantages and disadvantages of realistically shaped three-dimensional boundary-element models in MEG source localization were studied using computer simulations.

A Matlab toolbox for MEG analysis

New methods are constantly developed for data analysis. Since some of these tools are not easily implemented using the existing software, there was the need to develop an alternative toolbox. The toolbox ("4-D Toolbox") is implemented in Matlab, which is a flexible language suitable for signal processing and graphical visualization. The toolbox includes wavelet-based time-frequency analysis, a new technique for localization of sources of oscillatory activity, and a measure of transient phase-locking of two signals.

Independent Component Analysis

A comparison of different versions of the Independent Component Analysis (ICA) for extracting evoked MEG responses was carried out in collaboration with the Neural Networks Institute, Helsinki University of Technology. A software tool for applying ICA to neuromagnetic data was implemented.

Visualization

A new visualization method for brain surface was developed that combines the benefits of volume rendition and triangle mesh rendition. Texture mapped meshes produced by the method allow a fast and realistic-looking visualization with standard OpenGL-based graphics hardware. Texture-mapped cutting planes were used for visualizing inner structures with MCE data showing the activation areas.

fMRI preparations

Pilot functional magnetic resonance imaging studies were carried out with the Department of Radiology in Töölö hospital. Various sensory stimulators and software for presenting multimodal stimuli in fMRI experiments were tested. Some pilot fMRI studies were carried out with the Department of Radiology in Töölö hospital.

Collaboration with Datex-Ohmeda

In collaboration with researchers in Datex-Ohmeda Company, we have studied several mathematical methods to calculate an index which could reveal the complexity and entropy of a time-dependent MEG signal. Similar methods have been previously used as indicators of the depth of anesthesia. We have collected whole-scalp MEG data during different sleep stages from 5 subjects and are applying the methods to find an index which would correlate with the depth of sleep.

Rhythmically coupled neural networks

O. Jensen, R.Hari, K.Kaila

There are numerous reports on rhythmic coupling between separate brain networks. It has been proposed that this rhythmic coupling indicates exchange of information. So far, few computational models have been proposed which explore this principle and its potential computational benefits. Recent results on hippocampal place cells recorded from the rat provide new insight: it has been shown that information about space is encoded by the firing of place cells with respect to the phase of the ongoing theta rhythm. This principle is termed phase coding. A network reading the hippocampal output must inevitably also receive an oscillatory theta input in order to decipher the phase coded firing patterns. I have constructed a computational model of two coupled networks. The first network, modeling the hippocampal region, produces phase coded information by repeated sequence read out. The second network reads and decodes the hippocampal firing patterns. Both networks receive rhythmic theta drives with a variable phase difference. The network neurons are modeled as integrate-and-fire units. Computer simulations of the network models demonstrated that qualitatively different information is transferred from one network by changing only the phase of the theta input to the decoder. The proposed mechanism provides a computational principle for information transfer between oscillatory networks and might generalize to brain networks beyond the hippocampal region.

The role of GABAergic transmission in gamma and beta activity

Last year we conducted a MEG study demonstrating that visually evoked gamma responses (25-40 Hz) increase with voluntary hyperventilation (HV). Recent in vitro work on the rat hippocampus has demonstrated that alkalosis induced by an increase in CO₂ stabilizes spontaneous gamma oscillations and increases GABAergic transmission. Considering the inhibitory effect of GABAergic transmission, this finding seems counter-intuitive. Nevertheless, theoretical work and computer simulations of network models have provided a plausible explanation: even though the GABAergic feedback has an inhibitory effect on neuronal firing, it also facilitates firing synchrony. To test the possibility that the increase in visually evoked gamma responses during HV (which supposedly induces alkalosis) likewise is explained by an increase in inhibitory GABAergic transmission, we constructed a physiologically plausible network model of 100 Hodgkin-Huxley type model neu-

rons. When simulated on a computer, the model neurons were depolarized by an excitatory drive. This made the model neurons fire synchronously at ~40 Hz, i.e., the network produced evoked gamma activity. In accordance with our hypothesis, simulations demonstrated that an increase in GABAergic transmission produced an increase in evoked gamma responses.

TEACHING

COURSES AND OTHER TEACHING ACTIVITIES

Courses

Dos, Erkki Thuneberg, *Matalien lämpötilojen fysiikan teoria, (Low Temperature Physics: Theory)* (KYL.0.104)

Workshops

Graduate student research seminar at Himos 30.3 - 2.4.

Organized by Harry Alles

The purpose of this seminar was to give the graduate and undergraduate students of LTL a chance to present their progress after a similar seminar organized in Sjäkulla in March 1999. The total number of participants was 31 and altogether 17 presentations were given during the two-day meeting. Among these presentations there were also two pedagogical talks by Dr. Christian Urbina (CEA-Saclay) on the conductance of an atom and atomic contacts. The other topics included studies on vortices of superfluid ^3He , experimental work with carbon nanotubes as well as preparation for a search for the superfluid transition in liquid $^3\text{He}/^4\text{He}$ mixtures to name just a few.

Tuohilampi Seminar 24.5 - 25.5.

Organized by Teija Silén

The Brain Research Unit arranged a Seminar in Tuohilampi Congress Center, Espoo. The participants were 26. The scientific program was interesting and aroused a lot of discussion. The participants presented several studies, which showed differences between male and female brain function. In addition, effect of ball games on the brain function was speculated.

Teaching assistants

Mika Sillanpää served as a teaching assistant for *Matalien lämpötilojen fysiikan teoria (Low Temperature Physics: Theory)* (KYL.0.104).

Supervision of special projects

Riitta Hari supervised Mervi Valta's special project: *Tutkimus nopeiden näkö- ja kuuloärsykesarjojen havainnoimiskyvystä lukihäiriöisillä aikuisilla (Perception of rapid visual and auditory stimulus sequences in dyslexic adults)*.

Riitta Hari supervised Juha Järveläinen's special project *Ihmisen peilisolujärjestelmän aktivoitumisen riippuvuus katseltavan liikkeen laadusta, MEG-tutkimus (Activation of human mirror neuron system during observation of different kind of movements, MEG study)*.

Matti Hämäläinen supervised Jan Kujala's special projects *Kaksidipolimallin parametrien todennäköisyysjakaumat (Probability distribution of the two-dipole model parameters)*, *RAP-MUSIC (Analysis of MEG data using RAP-MUSIC)*, *Hemodynaamisten ja sähkömagneettisten aivokvantamismenetelmien yhteiskäyttö (Comparison of hemodynamical and electromagnetic brain images)*, and *Magneettiresonanssikuvien ja lähdealueiden vertailu AIR-ohjelmiston avulla (Alignment of magnetic-resonance images and source locations with AIR software)*.

Harry Alles supervised Heikki Junes' special project: *Simulations on the Shape of the Crystals Imaged by a Fabry-Pérot interferometer*.

Juha Tuoriniemi supervised Elias Pentti's special projects *Magneettinen suojaus matalissa lämpötiloissa: Cryoperm-10:n lämpökäsittely ja permeabiliteetti (Magnetic shielding at low temperatures: heat treatment and permeability of Cryoperm-10)*.

Juha Tuoriniemi supervised Elias Pentti's special project: *Rodiumin rautaepäpuhtauspitoisuuden määrittäminen resistiivisyysmittauksin (Determination of the iron-impurity concentration in rhodium by resistivity measurements)*.

ACADEMIC DEGREES

Diploma theses

Kirsi Juntunen graduated as M.Sc. Tech. from the Department of Engineering Physics and Mathematics on May 9. Her diploma thesis *Effects of eddy currents on the NMR spectra of a highly polarized metal sample* was done in the LTL. Supervisor: Juha Tuoriniemi.

Janne Viljas graduated as M.Sc. Tech. from the Department of Engineering Physics and Mathematics on May 9. His diploma thesis *Pinhole model for the Josephson π state in ^3He* was done in the LTL. Supervisor: Erkki Thuneberg.

Samu Taulu graduated as M.Sc. Tech. from the Department of Engineering Physics and Mathematics on May 11. His diploma thesis *Quality assurance software for a neuromagnetometer* was done in the Neuromag Oy and in the Brain Research Unit, LTL. Supervisor: Lauri Parkkonen.

Antti Finne graduated as M.Sc. Tech. from the Department of Engineering Physics and Mathematics on Nov 14. His diploma thesis *Niobium thin-film resonators for low-frequency NMR* was done in the LTL. Supervisor: Matti Krusius.

René Lindell graduated as M.Sc. Tech. from the Department of Engineering Physics and Mathematics on Dec 12. His diploma thesis *Spectroscopy in an ultrasmall Josephson junction using inelastic Cooper pair tunneling* was done in the LTL. Supervisor: Pertti Hakonen.

Paula Routama graduated as M.Sc. Tech. from the Department of Engineering Physics and Mathematics on Dec 12. Her diploma thesis *Making of a carbon nanotube based single electron transistor using electron beam lithography* was done in the LTL. Supervisor: Pertti Hakonen.

Ph.D. dissertations

Tommi Rajj defended his Ph.D. thesis *Neuromagnetic characterization of dynamic cortical networks supporting human cognition* for the degree of Doctor of Medicine at University of Helsinki, Department of Clinical Neurosciences on May 27. The opponent was Dr. Gabriel Curio from the Department of Neurology at the Freie Universität Berlin, Germany. The work, carried out in the Brain Research Unit, LTL, was supervised by Riitta Hari.

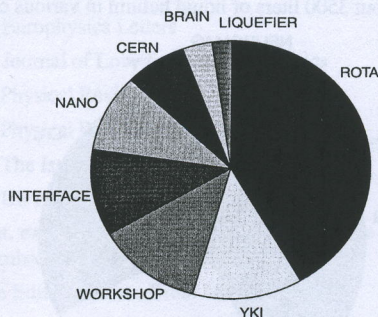
Roch Schanen defended his Ph.D. thesis *NMR measurements on the order-parameter field and its defects in rotating superfluid ^3He* at de l'université Joseph Fourier on October 25. The opponents were Dr. Olivier Avenel, Prof. Yuri Bunkov, Dr. Roland Combescot, Dr. Thierry Dombre, Prof. Matti Krusius, and Prof. Vladimir Mineev. The work, carried out in the LTL, was supervised by Matti Krusius.

Tauno Knuutila defended his Ph.D. thesis *Nuclear Magnetism and superconductivity in rhodium* on November 24. The opponent was Prof. Yasumasa Takano from University of Florida in Gainesville, Florida, USA The work, carried out in the LTL, was supervised by Juha Tuoriniemi.

TECHNICAL SERVICES

MACHINE SHOP

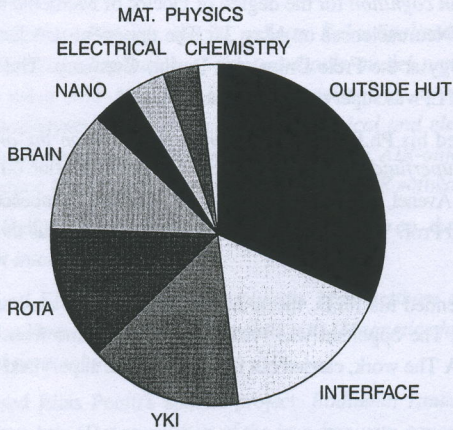
A. Huvila, **J. Kaasinen**, M. Korhonen, M. Lehtovuori, and K. Rauhanen.



The LTL workload on the workshop was 1897 machine hours. A total workload of 3556 hours includes also work for Institute of Biomedical Engineering and Materials Physics Laboratory as well as Advanced Energy Systems

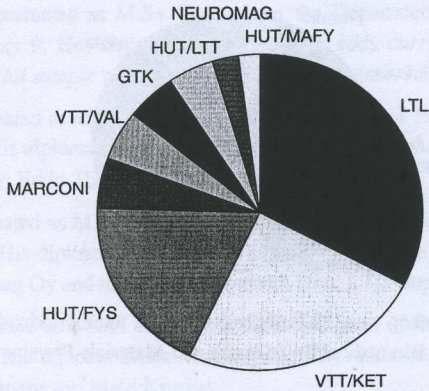
CRYOGENIC LIQUIDS

A. Isomäki, and A. Salminen



Helium The total amount of liquid helium delivered to the users was about 39000 liters.

The helium liquefaction equipment (Linde TCF-20) has been in use for over 10 years and its renewal will become necessary within the next 5 years. Our helium gas storage capacity is 12.5 cubic meters at high pressure (150 bars) which corresponds to about 2500 liquid liters. The liquid storage capacity is at present about 3500 liters of liquid helium in various cryogenic containers.



Nitrogen Our nitrogen liquefier (Linde - LINIT 25) was installed in 1996 and more than half of its production goes outside the LTL. The total amount produced was 39 900 liters. The distribution of the users is shown above.

ACTIVITIES OF THE PERSONNEL

PERSONNEL WORKING ABROAD

Leif Roschier Yale University, New Haven, Connecticut, USA, Sep 29 - Nov 30

EXPERTISE AND REFEREE ASSIGNMENTS

- Ahlskog Pre-examiner for the degree of licentiate of Anssi Lindell, University of Jyväskylä
- Berglund Advisory Editor, Cryogenics, Butterworth Heinemann, UK
Member, Finnish Academy of Technical Sciences
Member, International Cryogenics Engineering Committee, ICEC
Member, Svenska tekniska vetenskapsakademien i Finland
Referee, US National Science Foundation
- Fors Referee, Clinical Neurophysiology
Referee, Human Brain Mapping
Referee, Journal of Neurophysiology
Referee, NeuroReport
Referee, Stroke
- Hakonen Fellow, American Physical Society
Referee, Europhysics Letters
Referee, Journal of Low Temperature Physics
Referee, Physical Review B
Referee, Physical Review Letters
Referee, The Israel Science Foundation
Referee, US National Science Foundation
Opponent, examination for the degree of licentiate of Karin Andersson, Kungliga Tekniska Högskolan, Stockholm, Sweden
- Hari Associate Editor, Human Brain Mapping

Consultant, Department of Clinical Neurophysiology, Helsinki University Central Hospital (part-time)

Coordinator, EU Large-Scale Installation Neuro-BIRCH III, Espoo, Finland
Coordinator, Functional Brain Mapping, Finland-Taiwan Scientific Cooperation
Councilor, Organization for Human Brain Mapping 1997-2000
Member, Academia Europaea, UK
Member, Editorial Board of Brain Topography
Member, Editorial Board of Clinical Neurophysiology
Member, Editorial Board of Human Brain Mapping
Member, Editorial Board of inScight (web journal)

- Member, Editorial Board of Neuroimage
- Member, Editorial Board of Neuroscience Research
- Member, European Dana Alliance for the Brain
- Member, Finnish Academy of Sciences and Letters
- Chair of the Program Committee, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17, 2000
- Member of the Organizing Committee of 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17, 2000
- Member, Scientific Advisory Board of the National PET Center, Turku
- Member, Selection Panel for the Wiley Young Investigator's Award
- Member, Society for Neuroscience, USA
- Member, Steering Committee of the Helsinki Graduate School of Neurobiology
- Member, The American Physiological Society
- Member of Scientific Board, 10th European Congress of Clinical Neurophysiology, Lyon, France
- Partner, Human Frontier Science Research Grant RG 39-98 on action viewing
- Referee for grants, European Science Foundation, Switzerland
- Referee for grants, Wellcome Trust, UK
- Referee for Professorship, Clarkson University, NY, USA
- Referee for Professorship, McGill University, Montreal, Canada
- Referee for Senior Scientific Post, MRC, London, UK
- Referee, Audiology
- Referee, Brain
- Referee, Encyclopedia of the Human Brain
- Referee, Experimental Brain Research
- Referee, Cerebral Cortex
- Referee, Clinical Neurophysiology
- Referee, Hearing Research
- Referee, Human Brain Mapping
- Referee, Journal of Neurophysiology
- Referee, MIT Press
- Referee, Nature Neuroscience
- Referee, Neural Computation
- Hämäläinen Associate Editor, IEEE Transactions on Biomedical Engineering
- Referee, Human Brain Mapping
- Referee, IEEE Transactions on Biomedical Engineering
- Referee, Medical and Biological Engineering and Computing
- Referee, Physics in Medicine and Biology
- Jensen Referee, Journal of Neuroscience

- Krusius
- Referee, Neuroscience Research
 - Advisory Editor, Physica B: Condensed Matter
 - Fellow of the American Physical Society
 - Member of Board, Low Temperature Section, Condensed Matter Division, European Physical Society
 - Member, Academia Europaea, UK
 - Member, European Physical Society
 - Member, Finnish Academy of Sciences and Letters
 - Member, Finnish Physical Society
 - Member, Steering Group, European Science Foundation Network on Topological Defects – Non-equilibrium Field Theory in Particle Physics, Condensed Matter, and Cosmology
 - Member, International Advisory Board, International Conference on Quantum Fluids and Solids - GFS 2000, Minneapolis, 6-11 June, 2000
 - Member, Organizing Committee, International Conference on Quantum Fluids and Solids - GFS 2001, Konstanz, Germany, 21-27 July, 2001
 - Referee Statement Prepared for University of Jyväskylä
 - Referee Statement Prepared for University of Massachusetts,
 - Referee, European Science Foundation
 - Referee Statement Prepared for Technion Israel Institute of Technology
 - Referee, Physical Review Letters
 - Referee, Physical Review
 - Opponent for Doctoral Dissertation of Roch Schanen at de l'université Joseph Fourier, France on October 25th. The opponents were Olivier Avenel, Yuri Bunkov, Roland Combescot, Thierry Dombre, Matti Krusius, and Vladimir Mineev.
 - Secretary, Physics Group of Finnish Academy of Sciences and Letters
- Lounasmaa
- Advisory Editor, Europhysics Letters
 - Chairman, Advisory Committee of the 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17, 2000
 - Fellow, American Physical Society
 - Foreign Member, National Academy of Sciences of the USA
 - Foreign Member, Royal Swedish Academy of Sciences
 - Honorary Fellow, Indian Cryogenics Council
 - Honorary Member, Finnish Physical Society
 - Member, Academia Europaea, UK
 - Member, Board of the Center for Ultra-Low Temperature Research, University of Florida
 - Member, Commission A1/2, International Institute of Refrigeration
 - Member, European Physical Society
 - Member, Finnish Academy of Sciences and Letters

Member, Finnish Academy of Technical Sciences
Member, LUMA-panel set up by the Ministry of Education
Member, Research Council of HUT 1 Sep 1999 – 31 Jul 2000
Member, Societas Scientiarum Fennica

Mäkelä

Organizer and Chairman, XXXIII International Congress of Military Medicine, Helsinki, Jun 25–30
Scientific Organizer of poster symposium, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
Referee, Audiology & Neuro-otology
Referee, Clinical Neurophysiology
Referee, Ear and Hearing
Referee, Neuroscience
Secretary, Working Group for Defining a Research Program for the Military Health Care in the Near Future (2000–2005)

Paalanen

Chairman, Board of SOLIS (Educational Campaign of Finnish Physical Society for the Improvement of Physics Education in Highschools) - Mar 2000
Chairman, Selection Committee of Magnus Ehrnrooth Physics Prize
Coordinator of Low Temperature Physics Research, Finland-Taiwan Scientific Cooperation
Coordinator of ULTI III (Ultra Low Temperature Installation) Large Scale Installation in EU-funded IHP program Apr 1, 2000 - Mar 31, 2003
Fellow, American Physical Society
Member, Academia Europaea, UK
Member, Advisory Committee of 19th Nordic Semiconductor Meeting, Copenhagen, May 21-23, 2001
Member, Appointment Committee of Chief Scientist in the Institute of Physical and Chemical Research (RIKEN), Japan
Member, Board of Arkhimedes (Finnish Physical Journal)
Member, Board of High Speed Electronics Photonics, Nanoscience, and Quantum Devices Consortium in Chalmers University of Technology, Gothenburg, Sweden
Member, Board of Uudenmaan Rahasto of Finnish Cultural Foundation
Member, Commission C5 Low Temperature Physics, International Union of Pure and Applied Physics (IUPAP) (Sep 1, 1999 -)
Member, Editorial Board of Journal of Low Temperature Physics
Member, Finnish Academy of Sciences and Letters
Member, Finnish Academy of Technical Sciences
Member, International Advisory Committee of an American TV program on low temperature physics (Chairman Professor Russel Donnelly, University of Oregon, USA)
Member, Resource Review Board of ATLAS experiment at CERN

Member, Steering Committee of ESF-sponsored PiShift Network
Referee for appointment of two full professors in State University of New York, Stony Brook, USA
Referee for appointment of a full professor in University of Cincinnati, Ohio, USA
Referee for appointment of a full professor in Institute of Technology, Technion, Haifa, Israel
Referee, EU Science Programs
Referee, Journal of Low Temperature Physics
Referee, National Science Foundation, USA
Referee, Physical Review B
Referee, Physical Review Letters
Referee, Swedish Research Council for Engineering Sciences
Member, Editorial Board, Journal of Neuroimaging
Member, Organizing Committee, Neuroscience Finland 2000
Member, Organizing Committee, Symposium Optimising fMRI Experiments (Finland)
Member, Scientific Committee, ISBET 2000
Referee, Behavioural Brain Research
Referee, Brain
Referee, Cerebral Cortex
Referee, Clinical Neurophysiology
Referee, European Journal of Neuroscience
Referee, Experimental Brain Research
Referee, Human Brain Mapping
Referee, IEEE Transactions on Biomedical Engineering
Referee, Journal of Clinical Neurophysiology
Referee, Journal of Neuroimaging
Referee, Journal of Speech, Language, and Hearing Research
Referee, Neuroimage
Referee, Proceedings of the National Academy of Sciences, USA
Referee, Psychophysiology
Referee, Human Frontier Science Program
Reviewer for grant applications, Human Frontier Science Program
Reviewer for grant applications, The Wellcome Trust
Pre-examiner and opponent for the PhD thesis of Päivi Laarne, Tampere University of Technology
Principal investigator, NIH NS34533 hippocampus
Referee, Human Brain Mapping
Referee, Europhysics Letters

Salmelin

Tesche

Thuneberg

- Referee, Journal of Low Temperature Physics
Referee, Physical Review
Referee, Physical Review Letters
Referee, Physica Scripta
Thesis examiner of Shadyard Farhangfar, Jyväskylän yliopisto
- Tuoriniemi Referee, Physical Review Letters
Organizer, International ULTI Symposium on Low Temperature Physics under EU Large-Scale Facilities Programme (Jan 2001)
- Uutela Referee, Human Brain Mapping
Referee, Medical & Biological Engineering & Computing
- Volovik Associate editor, JETP Letters, Russia
Referee for appointment of an associate professor in Bilkent University, Turkey
Referee for National Science Foundation, USA
Referee for promotion to a personal professorship in Cambridge University, UK
Member of the evaluation committee in charge of reviewing the research activities of DSM/DRECAM/SPEC, Saclay, France, and DSM/DRFMC/SPSMS, Grenoble, France, November 2000
Organizer, International workshop, Microscopic Structure and Dynamics of Vortices in Unconventional Superconductors and Superfluids, Feb 28 - Mar 4, 2000, Max-Planck Institute for Physics of Complex Systems, Dresden, Germany
Organizer, International workshop, Analog Models for General Relativity, Rio de Janeiro, Brazil, Oct 16 - 20, 2000
Principal applicant in proposal ESF/PESC Scientific Programme "Cosmology in the Laboratory" (COSLAB)
Referee, National Science Foundation, USA
Referee, EPSRC, UK
Referee for promotion to professorship, University of Cambridge, UK

CONFERENCE PARTICIPATION AND LABORATORY VISITS

- Alary Poster, *Influence of the interstimulus interval on activation of the hand and foot SI cortices*. F. Alary, C. Simões, N. Forss, R. Hari, 12th International Conference on Biomagnetism, Biomag2000, Espoo, Finland, Aug 13-17
Poster, *Influence of the interstimulus interval on activation of the hand and foot SI cortices*. F. Alary, C. Simões, N. Forss, R.Hari, Society for Neuroscience, 30th Annual meeting, New Orleans, Louisiana, USA, Nov 4-9
- Ahlskog Poster, *Manipulation of carbon nanotube rings using the atomic force microscope*, 18th General Conference of the Condensed Matter Division of the European Physical Society, Montreux, Switzerland, Mar 13-17

Participation, AFM measurements of mechanical properties of carbon nanotubes, COST Short Term Scientific Mission, Katholieke Universiteit Leuven(VSM), Belgium, Jun 28-Jul 2

- Alles Invited talk, *Observations on ^3He crystals below 1 mK using an optical interferometer*, 18th General Conference of the Condensed Matter Division of the European Physical Society, Montreux, Switzerland, Mar 13-17
- Avikainen Poster, *Modulated activation of SI and SII cortices during execution and observation of hand actions*, Biomag2000, Espoo, Otaniemi, Finland, Aug 13 - 16
Invited talk, *Mirror neurons and somatosensory system*, HFSP0 Annual meeting, Kyoto, Japan, Oct 1 - 3
- Berglund Invited talk, *Ultramatlat lämpötilat, miten niitä aikaansaadaan ja mitataan, (Ultra low temperatures, how are they generated and measured)*, Luonnonfilosofian seuran vuosikokous, Helsinki, Finland, Mar 23
Consultation, *The new low temperature world record*, radio interview 5 min, Morning comments on Radio Extrem, Helsinki, Finland, Nov 27
- Blaauwgeers Oral presentation, *Vortex lines at the A-B interface in superfluid ^3He* , Annual Meeting of the Finnish Physical Society, Espoo, Finland, Mar 9-11
Oral presentation, *Measurements on continuous double-quantum vortices in superfluid ^3He -A*, International Symposium on Quantum Fluids and Solids QFS-2000, Minneapolis, Minnesota, USA, Jun 6-11
Oral presentation, *Measurements on continuous double-quantum vortices in superfluid ^3He -A*, User meeting of the EU Bayreuth Low Temperature Facility, Regensburg, Germany, Jul 14-16
Oral presentation, *The Helsinki experiments on rotating superfluid ^3He* , Lancaster, England, Oct 1-15
- Fors Invited talk, *Sensorimotor processing*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Fujiki Poster presentation, *Binaural interaction revealed using frequency-tagged amplitude-modulated sounds*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
Invited talk, *The present condition of the teaching of vocalization and singing, and the treatment of voice disorder in Finland.*, The 11th semiannual meeting of the Japan Association of Vocalization Instructors, Tokyo, Japan, Oct 12
Invited talk, *The present status of auditory evoked MEG*, The 30th annual congress of the Japanese Society of Clinical Neurophysiology, Kyoto, Japan, Dec 13-15
Participation, International Symposium on Inter-areal Functional Coupling, Kyoto, Japan, Dec 16-17
- Hakonen Opponent, Examination of the licentiate thesis by Karin Andersson "A Cooper pair turnstile made from a long, one dimensional array of Josephson junctions", Kunliga Tekniska Högskolan, Stockholm, Sweden, Jan 13
Lecture, *Dissipative phase transition in a mesoscopic Josephson junction*, Kunliga Tekniska Högskolan, Stockholm, Sweden, Jan 13-14

Invited talk, *Phase transitions in mesoscopic Josephson junctions induced by dissipation*, 18th General Conference of the Condensed Matter Division of the European Physical Society, EPS-CMD18, Montreux, Switzerland, Mar 13-17

Consultation, Collaboration with Frank Hekking at CNRS, Grenoble, France, Sep 26-Oct 1

Lecture, *Multiwalled carbon nanotubes as building blocks in nanoelectronics*, Grenoble, France, Sep 28

Hänninen

Poster, *Inhomogeneous scattering model for ^3He in aerogel*, Annual Meeting of the Finnish Physical Society, Espoo, Finland, Mar 9-11

Poster, *Inhomogeneous scattering model for ^3He in aerogel*, User meeting of the EU Bayreuth Low Temperature Facility, Regensburg, Germany, Jul 14-16

Hari

Invited talk, *Systeeminen neurotiede (Systems neuroscience)*, Neurotieteiden Instituutti -kokous, Hanasaaren kulttuurikeskus, Espoo, Finland, Jan 14

Invited talk, *Neuromagnetic view to the visual brain*, Symposium to celebrate the 60th birthday of Lea Hyvärinen, Helsinki, Finland, Jan 22

Site visit of evaluation group, PET Centrum, Turku, Finland, Feb 3

Invited talk, *Oppiminen, oppimisvaikeudet ja aivotoiminta (Learning, learning impairment, and brain function)*, Oppimisvaikeuksien tutkijamillennium, Helsinki, Finland, Feb 4

Invited plenary talk, *Human Mirror Neuron System: From Viewing to Action*, The First Lecture in Kuopio Neuroscience Lecture Series, Kuopio, Finland, Apr 3

Invited talk, *Magnetoencefalografiatutkimukset (Magnetoencephalography)*, Koulutustapahtuma, Tieteellinen hypnoosi ry, Aulanko, Finland, May 28

Session chairman, *Perception*, Sixth Annual Meeting of the Organization for Human Brain Mapping, San Antonio, Texas, USA, Jun 12-16

Session chairman, *Mapping the Senses Merging*, Sixth Annual Meeting of the Organization for Human Brain Mapping, San Antonio, Texas, USA, Jun 12-16

Participation, Organization for Human Brain Mapping, Council meeting, San Antonio, Texas, USA, Jun 13

Invited talk, *Magnetoencephalography - Olli's serious hobby*, Academician Olli Lounasmaa's 70 year anniversary symposium, Low Temperature Laboratory, Espoo, Finland, Aug 21

Invited plenary talk, *Magnetoencephalography: From physics laboratories to clinical praxis*, 10th European Congress of Clinical Neurophysiology, Lyon, France, Aug 26-31

Session chairman, Magnetoencephalography, 10th European Congress of Clinical Neurophysiology, Lyon, France, Aug 26-31

Invited talk, *The human mirror neuron system: Neuromagnetic recordings, Living for Brain Research: From Cell to Rhythm*, Farewell Symposium of Prof. F.H. Lopes da Silva, Amsterdam, The Netherlands, Sep 15

Session chairman, Workshop in Association of Prof. A. Damasio's Yrjö Reenpää lecture "Emotions and Consciousness", organizer The Finnish Cultural Foundation, Helsinki, Finland, Sep 22

Invited talk, *Ihmisaivot tutkimuskohteena (The Human Brain as the Research Object)*, Suomalaisia tiedenaisia -esitelmäsarja (Finnish female scientists), Helsinki, Finland, Sep 26

Visit, Kyoto University Medical School, Department of Brain Pathology, Kyoto, Japan, Sep 30

Invited talk, *Progress of the Helsinki team*, Human Frontier Science grant, Annual working meeting, Kyoto, Japan, Oct 1-3

Invited plenary talk, *Ihmisaivojen kuvantaminen: missä ollaan ja mihin pyritään? (Human brain imaging: where are we now and where are we aiming at?)*, Life2000 Biologisten Funktioiden Tutkimusohjelma, Avajaisseminaari, Helsinki, Finland, Oct 26

Invited talk, *Neuronal mass action in the human brain: the MEG approach*, The Ragnar Granit Centenary Symposium, Helsinki, Finland, Oct 29-31

Consultation, Radiohaastattelu peilisoluista (Radio interview about the mirror neuron system), YLE Radioattori ohjelma, Helsinki, Finland, Dec 10

Consultation, Visit to National Rehabilitation Center for the Disabled, MEG laboratory, Tokorozawa City, Saitama Prefecture, Japan, Dec 11

Invited plenary talk, *Magnetoencephalographic studies of human cognition: The mirror-neuron system*, The 30th Annual Congress of the Japanese Society of Clinical Neurophysiology, Kyoto, Japan, Dec 13-15

Invited talk, *Magnetoencephalography in the study of human brain function*, Institute of Economic Research, Kyoto University, Kyoto, Japan, Dec 15

Invited plenary talk, *Brain rhythms and reactivity of the human motor cortex*, International Symposium on Inter-areal Functional Coupling, Kyoto, Japan, Dec 16-17

Consultation, Visit to Department of Brain Pathophysiology, Human Brain Research Center, Kyoto University, Graduate School of Medicine, Kyoto, Japan, Dec 18

Helenius

Participation, Oppimisvaikeuksien tutkijamillennium (Learning Disability Symposium), Helsinki, Finland, Feb 4-5

Invited talk, *Mitä oppimisvaikeuksista tiedetään uusimman tutkimuksen valossa? (Reading evoked brain activation in dyslexia)*, Vantaan kaupungin henkilöstökoulutus: Oppimisvaikeuksien toteaminen koulutulokkailla, Helsinki, Finland, Feb 16

Oral presentation, *Time course of auditory word comprehension in dyslexia*, Sixth Annual Meeting of the Organization for Human Brain Mapping, San Antonio, Texas, USA, Jun 12-16

Invited talk, *Auditory cortical activation evoked by verbal and non-verbal sounds in dyslexia*, Literacy in the new millenium, Karolinska Institutet, Stockholm, Sweden, Jul 29-30

Invited talk, *Time course of auditory word comprehension in dyslexia*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland Aug 13-17

Invited talk, *Lukemisen ja puheen kuuntelun herättämä aivoaktivaatio lukivaikeuksisilla (Cortical organization of reading and speech processing in dyslexia)*, Helsinginseudun äidinkielenopettajat ry:n luki-ilta, Annatalo, Helsinki, Finland, Oct 4

Invited talk, *Kielenkäsittelyn aivomekanismit aikuisten lukivaikeuksissa (Functional organization of language in adult dyslexics)*, *Aikuisten oppimisvaikeudet ja niiden neuropsykologinen tutkiminen (Learning disabilities in adults and Neuropsychological testing)*, HYKS, Meilahden sairaala, Helsinki, Finland, Oct 27

Invited talk, *Kielen käsittelyn aivomekanismit aikuisten lukihäiriöissä (Functional organization of language in adult dyslexics)*, Vantaan kaupungin henkilöstökoulutus: Oppimisvaikeuksien toteaminen koulutulokkailla 2., Helsinki, Finland, Nov 22

Invited talk, *Cortical organization of reading and speech processing in dyslexia*, Brain Development, Helsinki, Finland, Dec 11-12

Jensen

Invited talk, *Frontal midline activity in the theta band (6-8 Hz) increases with memory load in a short-term memory task: a parametric MEG study*, Rigshospitalet Copenhagen, University Hospital Neurobiology Research Unit, Denmark, Apr 26

Poster, *Visually evoked gamma activity is increased during voluntary hyperventilation*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

Poster, *Visually evoked gamma activity is increased during voluntary hyperventilation*, Dynamical Neuroscience VIII, New Orleans, Louisiana, USA, Nov 3-4

Poster, *Ongoing theta activity (6-8 Hz) over the frontal midline increases with load in a short-term memory task: a parametric MEG study*, Society for Neuroscience, 30th Annual meeting, New Orleans, Louisiana, USA, Nov 4-9

Jousmäki

Lecture, *Neuro- and cardiomagnetic source imaging*, Graduate school: Functional research in medicine, Course: Medical imaging - theory and practice, Helsinki, Finland, Mar 13-16

Oral presentation, *Audiotactile Interactions*, International Sensory Aids Conference 2000, Exeter, UK, May 23-26

Session chairman, Special Interest Workshop: *Stimulators and Monitoring Devices*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

Lecture, *Audiotactile interactions*, Helsinki Summer School in Cognitive Neuroscience, Siuntio, Finland, Aug 13-17

Juottonen

Participation, XII Kliinisen Neurofysiologian päivät (12th Annual Meeting of Clinical Neurophysiology), Helsinki, Finland, Sep 14-16

Participation, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

Kajola

Lecture, *Tutorial: Digital Signal Processing*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 15

- Kirveskari Oral presentation, *Magnetoencephalography (MEG) in the stereotactic radiation therapy planning of intracranial lesions*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Kiviniemi Poster, *Neurocognitive effects of anomia treatment: an MEG study*, Sixth Annual Meeting of the Organization for Human Brain Mapping, San Antonio, Texas, USA, Jun 12-16
- Poster, *Neurocognitive effects of anomia treatment: an MEG study*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Knuutila Poster, *Nuclear magnetism and superconductivity in rhodium*, Annual Meeting of the Finnish Physical Society, Espoo, Finland, Mar 9-11
- Oral presentation, *Nuclear magnetism and superconductivity in rhodium*, User meeting of the EU Bayreuth Low Temperature Facility, Regensburg, Germany, Jul 14-16
- Koivikko Poster, *Diminished auditory mismatch fields in dyslexic adults*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Poster, *Diminished auditory mismatch fields in dyslexic adults*, Society for Neuroscience 30th Annual Meeting, New Orleans, Louisiana, USA, Nov 4-9
- Kopnin Invited talk, *Vortex dynamics and the problem of the transverse force in clean superconductors and Fermi superfluids*, Vortices in Unconventional Superconductors and Superfluids, Dresden, Germany, Feb 27-Mar 3
- Invited talk, *Magnetic quantization of electronic states in a d-wave superconductor*, *Theory of vortex dynamics*, Leiden, The Netherlands, Aug 20-26
- Invited talk, *Vortex formation by rapid thermal quench*, Vortex dynamics, European Science Foundation, Vortex Matter Workshop, Lunteren, The Netherlands, Aug 27-Sep 1
- Invited talk, *Vortex formation by rapid thermal quench*, European Science Foundation Scientific Network on Topological Defects - Non-Equilibrium Field Theory in Particle Physics, Cosmology and Condensed Matter, The Island of Capri, Naples, Italy, Sep 7-12
- Kopu Poster, *Vortex creation in two-dimensional superfluid ^3He - A flow*, International Symposium on Quantum Fluids and Solids, QFS 2000, Minneapolis, Minnesota, USA, Jun 6-11
- Krusius Invited lecture, *Vorticity in rotating ^3He superfluids*, NEDO 2nd International Workshop on Quantum Fluids and Solids, Honolulu, Hawaii, USA, Jan 27-29
- Invited talk, *Kvanttinesteiden topologiset defektit (Topological defects of quantum fluids)*, Kutsuseminaari tieteen ja tekniikan haasteet (Meeting on New Challenges in Science and Technology), Suomen Akatemia, Helsinki, Finland, Mar 24
- Invited lecture, *Topology and dynamics of quantized vorticity in ^3He superfluids*, User meeting of the EU Bayreuth Low Temperature Facility, Regensburg, Germany, Jul 14-16
- Invited lecture, *Quantized vorticity in superfluid ^3He - A: Structure and dynamics*, Workshop on Quantized Vortex Dynamics and Superfluid Turbulence, Newton Institute, Cambridge, UK, Aug 14-18

- Invited talk, *Forty years of low temperature physics*, Academician Olli Lounasmaa's 70 year anniversary symposium, Low Temperature Laboratory, Espoo, Finland, Aug 21
- Invited talk, *Neutron irradiation of rotating ^3He -B: where are the defects coming from?* European Science Foundation Scientific Network on Topological Defects - Non-Equilibrium Field Theory in Particle Physics, Cosmology and Condensed Matter, The Island of Capri, Naples, Italy, Sep 7-12
- Levänen
Poster, *Observing sign language*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Session chairman, Poster session, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Oral presentation, *Passive sign-language observation*, Society for Neuroscience, 30th Annual Meeting, New Orleans, Louisiana, USA, Nov 4-9
- Lounasmaa
Session chairman for two plenary talks, Annual Meeting of the Finnish Physical Society, Espoo, Finland, Mar 10
- Invited talk, *Aivojen vuosituhat on alkanut (Millennium of the brain has started)*, Studia Generalia lecture at the Faculty of Mathematics and Natural Sciences of the University of Turku, Turku, Finland, May 8
- Invited comment, *Arvioinnit, verkottuminen, säätiöt ja nobelit (Evaluations, networks, foundations, Nobel Prizes)*, Science Fair, Minne menet, Suomen tiede? (Finnish science, where are you heading?), Turku Congress Center, Finland, Oct 13
- Invited plenary talk, *Magnetoencephalography : An interdisciplinary effort*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Mäkelä
Invited talk, *MEG in preoperative functional mapping*, MEG Symposium in the Hospital of Sick Children, Toronto, Canada, Jan 17
- Invited talk, *The role of functional brain imaging in military medicine*, XXXIII International Congress of Military Medicine, Helsinki, Finland, Jun 25-30
- Lecture, *MEG localization of brain functions in neurological diseases*, Master Course of Cognitive Rehabilitation, Centro Farmaci Neuroattivi, Dipartimento di Scienze Motorie e Riabilitative, Università degli Studi, Ospedale San Martino, Genova, Italy, Jul 10
- Paalanen
Session chairman, Aspen Winter Conference on Condensed Matter Physics, Aspen Center for Physics, Aspen, Colorado, USA, Jan 9-14
- Invited talk, *Superconductor-insulator transition in an isolated Josephson junction*, International Symposium on Mesoscopic Superconductivity, M2000, Atsugi, Kanagawa, Japan, Mar 8-10
- Session chairman, International Symposium on Mesoscopic Superconductivity, M2000, Atsugi, Kanagawa, Japan, Mar 8-10
- Consultation, *How to organize a LT Conference*, Institute of Solid State Physics, Tokyo University, Japan, Mar 11
- Lecture, *Superconductor-insulator transition in single isolated Josephson junction*, Academia Sinica, Taipei, Taiwan, Mar 13

- Lecture, *Superconductor-insulator transition in single isolated Josephson junction*, National Tsing Hua University, Hsinchu, Taiwan, Mar 14
- Lecture, *Nanoelectronics at low temperatures*, Academia Sinica, Beijing, China, Mar 16
- Invited talk, *Carbon Nanotubes as Building Blocks in Nanoelectronics*, 32nd Workshop on Low Temperature Physics NT-32, Kazan, Russia, Oct 3-6
- Lecture, *Quality control in basic research*, Quality Control Seminar of Helsinki University of Technology, Espoo, Finland, Nov 16
- Parkkonen Visit, Universidad Complutense de Madrid, Spain, Jan 30-Feb 6
- Poster, *High-resolution magnetometer and gradiometer recordings of spike-like(600 Hz) SEF bursts*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Pohja Poster, *Cerebellar infarct decreases rhythmic activity outflow from the motor cortex*, Federation of European Neuroscience FENS 2000, Brighton, UK, Jun 25-28
- Raij Session chairman, Poster session, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Poster, with Kimmo Uutela and Riitta Hari, *Audiovisual integration of letters in the human brain*, Biomag 2000, Helsinki University of Technology, Espoo, Finland, Aug 13-17
- Radio interview, *Absoluuttinen sävelkorva (Absolute Pitch)*, Radio NOVA, Finland, Aug 13-17
- Roschier Oral presentation, *High frequency low temperature amplifier for SET applications*, European meeting on the Technology and Application of SET-Devices, Braunschweig, Germany, Jun 5-6
- Oral presentation, *Steps towards carbon nanotube single electron transistor*, 4th Alcove Thursday Seminar, Yale University, New Haven, Connecticut, USA, Oct 26
- Oral presentation, *Steps towards carbon nanotube single electron transistor*, Special Seminar, Cornell University, Ithaca, New York, USA, Dec 1
- Ruohio Oral presentation, *Experiments on A-B phase boundary in rotating superfluid ^3He* , European Science Foundation Scientific Network on Topological Defects - Non-Equilibrium Field Theory in Particle Physics, Cosmology and Condensed Matter, The Island of Capri, Naples, Italy, Sep 7-12
- Salmelin Session chairman, Biological and medical physics, Annual Meeting of the Finnish Physical Society, Espoo, Finland, Mar 9-11
- Session chairman, Neurocommunication, Neuroscience 2000 Finland Symposium, Helsinki, Finland, Mar 16-17
- Invited talk, *Dynamics of reading*, EU Program: Connectivity in language rehabilitation in Europe, 1st Meeting, Lisbon, Portugal, Jun 3
- Invited talk, *Dyslexia, stuttering, and beyond*, EU program: Connectivity in Language Rehabilitation in Europe, 1st Meeting, Lisbon, Portugal, Jun 3
- Poster, *Neurophysiology of single-word reading in stutterers and fluent speakers*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

Session chairman, *Cognition and language*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

Invited talk, *Unfolding the cortical dynamics of fluent and impaired reading with MEG*, Helsinki Summer School of Cognitive Neuroscience, Helsinki, Finland, Aug 17-22

Invited talk, *MEG and functional neuroanatomy of language processing*, 10th European Congress of Clinical Neurophysiology, Lyon, France, Aug 26-30

Invited talk, *MEG: Kielelliset prosessit (MEG: Language processes)*, XII Kliinisen neurofysiologian päivät (12th Annual Meeting of Clinical Neurophysiology), Helsinki, Finland, Sep 14-16

Invited talk, *Fysiikan lait ja aivotointa (Laws of physics and brain function)*, Helsingin seudun Duodecim -seuran kokous: Aivot työssä (The working brain), Espoo, Finland, Oct 4

Opponent, PhD thesis defence of Päivi Laarne: *Implementation of a realistic conductivity model for the head*, Tampere, Finland, Oct 17

Poster, *Neurophysiology of single-word reading in stutterers and fluent speakers*, Sixth Annual Meeting of the Organization for Human Brain Mapping, San Antonio, Texas, USA, Jun 12-16

Seppä

Poster, *MEG Source visualization with texture-mapped triangle meshes*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

Silén

Lecture, *Aivot, tärkein pääomamme (Brain, our most important capital)*, Heureka-yleisöluento, Tiedekeskus Heureka, Finland, Mar 19

Oral presentation, *Uutta tietoa aivotutkimuksesta (New information about brain research)*, Huomenta Suomi, MTV3, Mar 19

Poster, *Abnormal reactivity of the 20-Hz mu rhythm in ULD*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

Oral presentation, *Modified sensorimotor activity in ULD without GS*, 4th European Congress of Epileptology, Florence, Italy, Oct 7-12

Invited talk, *Aivotointinnan uudelleenmuotoutuminen (Plasticity)*, Geriatrisen hoidon seminaari, Helsingin yliopisto, Finland, Nov 8

Sillanpää

Oral presentation, *Density of states in mesoscopic superconductor-ferromagnet structures*, Macroscopic Quantum Coherence and Computing II, Naples, Italy, Jun 14-17

Simões

Poster, *Overlap of finger representations in somatosensory cortices*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

Poster, *Hemispheric difference in SII activation for tactile and electric median nerve stimulation*, Society for Neuroscience, 30th Annual Meeting, New Orleans, Louisiana, USA, Nov 4-9

Tarkiainen A.

Participation, Neuroscience 2000 Finland, Natural History Museum, Helsinki, Finland, Mar 16-17

Poster, *Dynamics of face perception in the occipito-temporal cortex*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

- Poster, *Spatio-temporal organization of face versus letter-string perception in the occipito-temporal cortex*, Society for Neuroscience, 30th Annual Meeting, New Orleans, Louisiana, USA, Nov 4-9
- Taulu Participation, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Thuneberg Invited talk, *Theory for Josephson effects in superfluid ^3He* , NEDO 2nd International Workshop on Quantum Fluids and Solids, Honolulu, Hawaii, USA, Jan 27-29
- Invited talk, *Theory for superfluid ^3He in aerogel*, NEDO 2nd International Workshop on Quantum Fluids and Solids, Honolulu, Hawaii, USA, Jan 27-29
- Session chairman, Superfluid and normal liquid ^3He , NEDO 2nd International Workshop on Quantum Fluids and Solids, Honolulu, Hawaii, USA, Jan 27-29
- Oral presentation, *New calculations on the Josephson pi state in ^3He* , International Symposium on Quantum Fluids and Solids, QFS 2000, Minneapolis, Minnesota, USA, Jun 6-11
- Poster, *Hydrostatic parameters of superfluid ^3He* , International Symposium on Quantum Fluids and Solids, QFS 2000, Minneapolis, Minnesota, USA, Jun 6-11
- Talk, *Pi state in ^3He Josephson junctions*, Physics Department and Helsinki Institute of Physics, University of Helsinki, Finland, Sep 12
- Invited talk, *Pi state in ^3He Josephson junctions*, Modern Problems of Condensed Matter Physics, Tbilisi, Georgia, Oct 16-21
- Invited talk, *Pi state in ^3He Josephson junctions*, University of Oulu, Finland, Oct 25
- Invited talk, *Pi state in ^3He Josephson junctions*, Åbo Akademi, Turku, Finland, Nov 1
- Tsepelin Poster, *Nucleation and growth of ^3He crystals below 1mK*, Annual Meeting of the Finnish Physical Society, Espoo, Finland, Mar 9-11
- Lecture, *Morphology and growth of ^3He crystals below 1mK*, Leiden University, The Netherlands, Apr 26-29
- Poster, *Morphology of ^3He crystals: new types of facets*, International Symposium on Quantum Fluids and Solids, QFS 2000, Minneapolis, Minnesota, USA, Jun 6-11
- Oral presentation, *Morphology and growth of ^3He crystals below 1mK*, User meeting of the EU Bayreuth Low Temperature Facility, Regensburg, Germany, Jul 14-16
- Uutela Invited talk, *Minimum current estimate*, Minisymposium on Anisotropic Modelling in Bioelectromagnetism, Espoo, Finland, May 18-20
- Poster, *Audiovisual integration of letters in the human brain*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Poster, *ICA comparison of blind separation of evoked responses*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Poster, *Correcting for head movements in MEG inverse problem*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17

- Vanni Poster, *Parallel activation of primary visual and parieto-occipital cortices*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Vihla Poster, *Detection of spectral changes: natural vowels versus two-frequency sounds*, 12th International Conference on Biomagnetism - Biomag2000, Espoo, Finland, Aug 13-17
- Participation, Helsinki Summer School in Cognitive Neuroscience, Siuntio, Finland, Aug 17-22
- Viljas Poster, *Pinhole model for the Josephson pi state in $^3\text{He-B}$* , User meeting of the EU Bayreuth Low Temperature Facility, Regensburg, Germany, Jul 13-16
- Volovik Opponent, second doctor dissertation by B. Dumesh, Kurchatov Institute, Moscow, Russia, Jan 19
- Invited talk, *Superfluids at ultralow temperature: Landau critical velocity vs. event horizon in black hole physics*, NEDO 2nd International Workshop on Quantum Fluids and Solids, Honolulu, Hawaii, USA, Jan 27-29
- Invited talk, *Monopoles, fractional vortices and fractional flux in unconventional superconductors*, International Workshop on Microscopic Structure and Dynamics of Vortices in Unconventional Superconductors and Superfluids, Max Planck Institute, Dresden, Germany, Feb 28-Mar 4
- Invited talk, *Trous noirs et relations avec la matière condensée*, Colloque GDR, Structures non perturbatives en théorie des champs et des cordes, École Normale supérieure de Lyon, France, May 2-4
- Invited talk, *Cosmology and superfluid ^3He* , Seminar at the Institute Laue-Langevin, Grenoble, France, May 5
- Invited talk, *Vortices observed and to be observed*, International Symposium on Quantum Fluids and Solids QFS-2000, Minneapolis, Minnesota, USA, Jun 5-11
- Opponent, Second doctor dissertation by A. Kamenshchik, Landau Institute, Moscow, Russia, Jun 30
- Lecture, *Momentum space topology: $^3\text{He-A}$ vs Standard Model, spin current QHE, etc*, XVIII Center for Physics of Fundamental Interactions, Autumn School on Topology of Strongly Correlated Systems, Instituto Superior Técnico, Lisbon, Portugal, Oct 8-13
- Session chairman, XVIII Center for Physics of Fundamental Interactions, Autumn School on Topology of Strongly Correlated Systems, Instituto Superior Técnico, Lisbon, Portugal, Oct 8-13
- Invited talk, *Effective gravity and quantum field theory in superfluids*, International workshop on Analog Models of General Relativity, Rio de Janeiro, Brazil, Oct 16-20

AWARDS

The Wiley Young Investigator Award was presented to Docent **Riitta Salmelin** of the Brain Research Unit during the 6th Annual meeting of the Organization for Human Brain Mapping in San Antonio, Texas. The award was now given for the fifth time for valuable contributions in character-

izing human brain function using modern functional imaging techniques. The Brain Research Unit of the Low Temperature Laboratory has done pioneering work in elucidating human cortical dynamics by means of multichannel magnetoencephalography (MEG) recordings. Riitta Salmelin has investigated, in particular, cortical correlates of language perception and production and their disturbances.

The Finnish Scientific Society awarded Academician **Olli V. Lounasmaa** a Silver Medal on Aug 21st.

Academician **Olli V. Lounasmaa** received an honorary degree of Doctor of Medicine, University of Helsinki on May 12th.

LTL SEMINAR SERIES

RESEARCH SEMINARS ON LOW TEMPERATURE PHYSICS

Organized by Matti Krusius and Pertti Hakonen

Kurt Gloos, Darmstadt University, Germany: *The horizon of Josephson point contacts*, Feb 14

Adriaan Schakel, Freie Universität, Berlin, Germany: *What on earth is duality?*, Feb 21

Reinhard König, Universität Bayreuth, Germany: *Superconductivity of Pt metal*, Feb 22

Vladimir Eltsov, LTL: *Experiments on vortices and vortex sheet in superfluid ^3He -A*, Feb 25

Grigory Volovik, LTL: *Monopoles and fractional vortices in chiral superconductors*, Feb 25

Frank Hekking, Magistere-CNRS, Grenoble, France: *Interaction constants and dynamic conductance of a gated wire*, Mar 6

Ulf Leonhardt, Royal Institute of Technology, Stockholm, Sweden, *Light in moving media*, Mar 21

Jens Siewert, University of Catania, Italy, *Coherent tunneling processes in SET with superconducting electrodes*, Mar 22

Jens Siewert, University of Catania, Italy, *Quantum computation using circuits of small Josephson junctions*, Mar 23

Cristian Urbina, CEA-Saclay, France: *What determines the conductance of an atom?*, Mar 30

Per Hedegård, The University of Copenhagen, Denmark: *Interdependence of magnetism and superconductivity in the borocarbide $\text{TmNi}_2\text{B}_2\text{C}$* , Apr 13

Alexander Parshin, Kapitza Institute for Physical Problems, Moscow, Russia: *Facet growth of ^3He crystals*, Apr 14

Erkki Thuneberg, LTL: *Theory of pi-state in ^3He -B Josephson junction*, May 30

GriSha Volovik, LTL: *Vortices observed and to be observed*, May 30

Rob Blaauwgeers, LTL: *Measurements on continuous double-quantum vortices in ^3He -A*, May 30

Takafumi Kita, Hokkaido University, Sapporo, Japan: *Vortices and quasiparticles in the mixed state in chiral and d-wave superconductors*, Jun 14

Jason Hogan-O'Neill, Laboratory of Physics, HUT, Finland: *Pi-rings and frustration in high temperature superconductors*, Jun 15

Victor Yakovenko, University of Maryland, USA: *Electrons on edge*, Jun 16

David Schaeffer, Université Joseph Fourier, France: *Superconducting microstrip resonators for dissipation measurements in nanotubes*, Jun 20

- Mohamed Soltani, University of Annaba, Algeria: *Some aspects of studying amorphous materials based on rare earth transition metal alloys*, Jul 20
- Robert Richardson, Cornell University, Ithaca, USA: *Why is it important for the public to know about science?*, Aug 22
- Jaakko Koivuniemi, CERN, Switzerland: *The present status of the COMPASS collaboration at CERN*, Aug 23
- George Pickett, University of Lancaster, UK: *Superfluid turbulence in non-rotating ^3He* , Aug 23
- Alexander Andreev, Kapitza Institute for Physical Problems, Moscow, Russia: *Mesoscopics and superconductivity*, Aug 31
- Hanna Viertiö-Oja, Datex-Ohmeda Division, Instrumentarium Corp: *Entropy of the EEG: A measure of consciousness?*, Sep 11
- Juha Hassel, State Research Center, Finland: *Bloch oscillation transistor*, Sep 11
- Edouard Sonin, Hebrew University of Jerusalem, Israel: *Magnus force, Aharonov-Bohm effect, and Berry phase in superfluids*, Sep 14
- Andrei Zaikin, Institute for Nanotechnology, Forschungszentrum Karlsruhe, Germany: *Electron transport through mesoscopic SNS junctions and superconducting quantum dots*, Sep 21
- Robert Duncan, University of New Mexico, USA: *Dynamics of liquid ^4He at the correlation length scale*, Oct 13
- Zdenek Janu, Institute of Physics, Praha, Czech Republic: *Nature of superconducting transition in high-Tc superconductors*, Nov 2
- Aarne Oja, VTT Automation, Finland: *Microelectromechanical components for metrology*, Nov 13
- Vladimir Kravtsov, International Centre for Theoretical Physics, Trieste, Italy: *Mesoscopic conduction fluctuations under ac pumping*, Nov 23
- Yasumasa Takano, University of Florida, Gainesville, Florida, USA: *Pressure measurements in adiabatically demagnetized solid ^3He* , Nov 23
- Tauno Knuutila, LTL: *Nuclear magnetism and superconductivity in Rhodium*, Nov 24
- Yuri Barash, Lebedev Institute, Russia: *Low-temperature magnetic penetration depth in high-temperature superconductors: Zero-energy bound state and impurity effects*, Nov 29

RESEARCH SEMINARS OF THE BRAIN RESEARCH UNIT

Organized by Päivi Helenius

- Christo Pantev, University of Münster: *Recent MEG-results*, Jan 10
- Teija Silen, LTL: *Modified activation of motor cortex in Unverricht-Lundborg type progressive myoclonus epilepsy patients*, Jan 17
- Flamine Alary, LTL: *Evoked potentials induced by a passive movement of the forefinger - healthy subjects and stroke patients*, Jan 24
- Sari Avikainen, LTL: *Action viewing in Asperger subjects*, Jan 31
- Yung-Yang Lin, Veterans General Hospital, Taipei, Taiwan: *Somatosensory evoked responses to light touch*, Feb 7
- Minna Vihla and Päivi Helenius, LTL: *Article reviews*, Feb 14
- Kimmo Uutela, LTL: *Foveal attention modulates responses to peripheral stimuli*, Feb 21
- Linda Stenbacka, LTL: *Comparisons between dipole and MCE analysis*, Feb 28

- Anya Hurlbert, University of Newcastle, Newcastle upon Tyne, UK: *Models of intra modal and cross-modal interactions*, Mar 6
- Hideki Yoshida, Tohwa University, Japan: *Human cognitive response without sensory processing: A MEG study*, Mar 13
- Luciano Fadiga, University of Parma, Italy: *Electrophysiological approaches to motor representations in humans*, Mar 20
- Erol Basar, Lübeck, Germany: *Grandmother percept is multiple oscillations - A tentative approach to extend Sherringtons single-neuron doctrine*, Mar 27
- Matti Hämäläinen, LTL: *Xfit (5.2.1) training*, Apr 3
- Topi Tanskanen, LTL: *Effects of spatial frequency on the temporal dynamics of visual information processing*, Apr 10
- Cristina Simões, LTL: *Overlap of finger representation in somatosensory cortices*, Apr 17
- Antti Tarkiainen, LTL: *Dynamics of face perception in the occipito-temporal cortex*, May 8
- Jani Kujala, LTL: *Coherence imaging: Development of a tool for studying dynamics of cortico-cortical interactions*, May 22
- Hanna Koivikko, LTL: *Article review*, Jun 5
- Veijo Ilmavirta, Innovation Center, Helsinki University of Technology: *Valtion virkamiehen yksityisektorille tekemiä töitä rajoittavat säännökset (The rules that restrict the work that civil servant does for the private sector)*, Sep 4
- Riitta Salmelin, Päivi Helenius, Flamine Alary, Minna Vihla and Topi Tanskanen, LTL: *Conference greetings*, Sep 18
- Ramesh Gulrajani, Institute of Biomedical Engineering, Université de Montréal, Canada: *The forward problems of electrocardiography and electroencephalography*, Oct 2
- Ole Jensen, LTL: *4D Toolbox*, Oct 9
- Antti Tarkiainen, Cristina Simões and Ole Jensen, LTL: *Neuroscience regards*, Oct 13
- Kimmo Utela, LTL: *Basics of 'Presentation'*, Oct 16
- Simo Vanni, LTL: *Visual mapping*, Oct 30
- Katri Kiviniemi, LTL: *Aphasia review*, Nov 6
- Antti Tarkiainen, Cristina Simões and Ole Jensen, LTL: *Neuroscience regards*, Nov 13
- Hanna Koivikko, Topi Tanskanen and Flamine Alary, LTL: *Neuroscience regards*, Nov 20
- Sari Avikainen, LTL: *Superior temporal sulcus, Review*, Dec 4
- Marjatta Pohja and Teija Silén, LTL: *Motor cortex and progressive myoclonus epilepsy - A Review*, Dec 18

LOW TEMPERATURE PHYSICS PUBLICATIONS

JOURNAL ARTICLES

- Ahlskog, M., Tarkiainen, R., Roschier, L., and Hakonen, P., *Single-electron transistor made of two crossing multiwalled carbon nanotubes and its noise properties*, Applied Physics Letters **77** (2000) 24, 4037-4039, (2000073)
- Berglund, P., Gehring, R., Koivuniemi, J., Kyynäräinen, J., and Takabayashi, N., *Dilution refrigerator for COMPASS polarized target*, Physica B **284-288** (2000) 2012-2013, (C2000041)

- Blaauwgeers, R., Eltsov, V.B., Krusius, M., Ruohio, J.J., and Schanen, R., *NMR measurement of quantized vortex lines in rotating ^3He -A*, Physica B **284-288** (2000) 250-251, (C2000035)
- Blaauwgeers, R., Eltsov, V.B., Krusius, M., Ruohio, J.J., Schanen, R., and Volovik, G.E., *Double-quantum vortex in superfluid ^3He -A "letters to nature"*, Nature **404** (2000) 471-473, (2000013)
- Eltsov, V.B., *Numerical simulations of the multiply-connected vortex sheet in ^3He -A*, Journal of Low Temperature Physics **121** (2000) 4/6, 387-392, (2000085)
- Eltsov, V.B., Blaauwgeers, R., Krusius, M., Ruohio, J.J., and Schanen, R., *Dynamic response of the equilibrium vortex sheet*, Physica B **284-288** (2000) 252-253, (C2000036)
- Eltsov, V.B., Kibble, T.W.B., Krusius, M., Ruutu, V.M.H., and Volovik, G.E., *Composite defect extends analogy between cosmology and ^3He* , Physical Review Letters **85** (2000) 22, 4739-4742, (2000067)
- Hakonen, P.J., Kiviranta, M., Penttilä, J.S., and Paalanen, M.A., *Noise measurements on single electron transistors using bias switching read-out*, The European Physical Journal Applied Physics **11** (2000) 227-229, (2000062)
- Hänninen, R. and Thuneberg, E., *Superfluid density for ^3He in aerogel assuming inhomogeneous scattering*, Physica B **284-288** (2000) 303-304, (C2000037)
- Härme, J.P.H., Alles, H., Babkin, A., Jochemsen, R., Parshin, A.Y., Tsepelin, V., and Tvalashvili, G., *Optical observation of ^3He crystal at mK-temperatures*, Physica B **284-288** (2000) 349-350, (C2000038)
- Ishii, H. and Hakonen, P., *Nuclear spin relaxation at ultralow temperatures*, Physica B **284-288** (2000) 1706-1707, (C2000076)
- Knuutila, T.A., Tuoriniemi, J.T., and Lefmann, K., *Relaxation of polarized nuclei in superconducting rhodium*, Physical Review Letters **85** (2000) 12, 2573-2576, (2000054)
- Knuutila, T., Martikainen, J., Rasmussen, F., and Tuoriniemi, J., *Double-spin-flip mode of rhodium nuclei*, Physica B **284-288** (2000) 1700-1701, (C2000042)
- Koivuniemi, J. and Krusius, M., *Noise temperature of cryogenic FET amplifier with high-Q resonator*, Physica B **284-288** (2000) 2149-2150, (C2000039)
- Koivuniemi, J. and Krusius, M., *Parametric amplification with a high-Q LC resonator*, Physica B **284-288** (2000) 2147-2148, (C2000040)
- Kopnin, N.B. and Vinokur, V.M., *Magnetic quantization of electronic states in d-wave superconductors*, Physical Review B **62** (2000) 14, 9770-9779, (2000059)
- Kopu, J. and Thuneberg, E.V., *Calculation of NMR line shape in rotating superfluid ^3He -B*, Physica B **284-288** (2000) 256-257, (C2000044)
- Kopu, J., Hänninen, R., and Thuneberg, E.V., *One-dimensional textures and critical velocity in superfluid ^3He -A*, Physical Review B **62** (2000) 18, 12374-12380, (2000064)
- Kopu, J., Schanen, R., Blaauwgeers, R., Eltsov, V.B., Krusius, M., Ruohio, J.J., and Thuneberg, E., *NMR line shape of rotating ^3He -B at large counterflow velocity*, Journal of Low Temperature Physics **120** (2000) 3/4, 213-232, (2000063)

- Leonhardt, U. and Volovik, G.E., *How to create an Alice string (half-quantum vortex) in a vector Bose-Einstein condensate*, JETP Letters **72** (2000) 2, 46-48, (2000053D)
- Leonhardt, U. and Volovik, G.E., *How to create an Alice string (half-quantum vortex) in a vector Bose-Einstein condensate*, Pis'ma v Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki **72** (2000) 2, 66-70, (2000053D)
- Lounasmaa, O.V., *Nicholas Kurti in memoriam*, Physica B **280** (2000) 1-3, (C2000029)
- Luusalo, R., Husmann, A., Kopu, J., and Hakonen, P., *Pseudo-contact angles and pinned vorticity in superfluid ^4He* , Physica B **284-288** (2000) 147-148, (C2000045)
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Appendix

REPORT OF THE EVALUATION OF THE LOW TEMPERATURE LABORATORY

1. Overview of the situation

This report is a follow-up of a similar evaluation carried out three years ago, partly with the same persons on the Evaluation Board. We have noticed with satisfaction that many of the recommendations made at that time have been taken into serious consideration and their implementation has been started; we comment on these in the detailed discussions below. We do, however, feel that the time taken to affect the changes has been too long. We do appreciate the difficulties posed by economy and size in a small country, but the aim of a center of excellence is to produce first rate research in a rapidly developing and changing international environment.

There is no doubt that most of its activities qualify LTL of HUT as a center of excellence. The experimental work involving superfluid ^3He and quantum crystals is of highest standard world wide. In some aspects the Laboratory is virtually without competition. A continuing close collaboration with theorists is likely to secure this status in that research area for a while. As became clear from the discussions, some other parts of the laboratory related with physics research might have difficulties in requesting the status of center of excellence, if they would stand alone.

The longest ongoing study in the Low Temperature Laboratory involves the properties of liquid and solid ^3He . At the present, this study is divided into two separate experimental areas: 1) The study of topological objects in macroscopic quantum systems, involving superfluid ^3He and to a much lesser degree, some of the non-s-wave superconductors; and 2) Interfaces in quantum systems, which has included both studies of ^3He and ^4He solid-liquid interfaces. In the Activity Report and Research Plan 1997-2003 given to the Advisory Board, these activities are grouped together along with studies of nuclear magnetism as parts of 'ultralow temperature physics', which represents 40% of the total research effort of the Laboratory.

Again unmatched is the earlier experimental work on nuclear magnetism where the Laboratory, together with the Hahn-Meitner Institute in Berlin, has ruled the market. According to previous recommendations, this type of activity has been reduced in favour of new work on superfluidity of ^3He - ^4He mixtures.

The Evaluation Board is concerned about the development of the nanophysics part of the program. Here, unlike in the other branches mentioned above, the Laboratory has to compete with a large and aggressive community world wide. We have the impression that the Laboratory does not belong to the major players in this area of research. Even if progress has occurred since the last report, see below, we feel that the laboratory needs a more focussed scientific profile and a more aggressive approach. The content of the publication list certainly supports this impression.

The brain research Unit has been active at an internationally excellent level and it has developed its scope and structure in a positive way. The Evaluation Board however, considers that the process of acquisition of the fMRI facility has been too slow. The Board regrets this delay and notes that it is important for the future scientific development of the Unit that the technical abilities of the Unit will

continue to be strengthened. In addition the present organisation needs to be seriously considered in order to enhance its efficiency.

The experimental activities of the Laboratory have been excellently supported by theoretical work. This is partly based on the personnel in the Laboratory, but also ad hoc international collaborators have been solicited. This has led to very good results, but one may question the efficiency of such temporary arrangements in providing the stability and diversity required on a longer time scale.

The time available for the procedure on site was certainly at the lower limit of anything that is needed to provide a reasonable and useful evaluation report. In particular, the time available for the oral presentations and the possibility for subsequent questions and discussions were obviously too short. We also felt that the discussions within the evaluation group were somewhat hampered by time limitations.

2. Liquid Helium

Within the past three years, studies of topological singularities in superfluid ^3He using the ROTA cryostat has continued to show considerable productivity. In addition, Matti Krusius has been honoured for his work in this field by being named co-recipient of the 1999 Fritz London Memorial Award, the most prestigious prize given in the field of low temperature physics. The emphasis of the ROTA work has shifted over time from the discovery and characterisation of the various vortex core structures to their spatial distributions, and finally to studies of nucleation processes. This has resulted in a remarkable picture of vortex behaviour in superfluidity in ^3He . Additional studies of novel spin precession in ^3He B and vortex mobility in UPt_3 have also been reported, which tend to complement some aspects of the ^3He vortex studies. The Board notes the high level of sophistication of this work, and the singular nature of the LTL's contributions in this area.

The problem we see with this work is that it has been at the forefront of the field for a long time. Its most outstanding results have essentially put all competitors out of the business. Thus the motivation to continue the work in the formerly successful directions is decreasing. Instead of continuing this activity doing incremental work in the area where the laboratory leads the world, it should strike out into new directions, where the prospects of success may appear more hazardous but challenging.

However, in the next three years the emphasis in vortex studies is expected to shift again, to studies of the interaction of various vortex core structures, particularly across a stabilised ^3He A-B interface. In addition, the work will move to a new cryostat capable of allowing studies to be carried out at considerably lower temperatures in the 'collisionless regime'. The Board feels that both of these new areas have considerable potential for new discoveries, and at the very least, the planned experiments should substantially increase our understanding of textural singularities in macroscopic quantum systems.

3. Nuclear Magnetism and Helium Mixtures

The research group, previously active in nuclear magnetism, runs one of the most powerful refrigeration systems for cooling matter into the submillikelvin range of temperatures. They have outlined a novel effort to create ^3He superfluidity in a saturated ^3He - ^4He solution by utilising the dilution cooling of the ^3He which will occur upon the addition of more superfluid ^4He . Their intention

of cooling mixtures of the two isotopes of He into their possible superfluid state is a major task, again demanding high technical skills. They plan to utilise the apparatus mentioned above and some new, although imported, ideas for cooling the mixtures. The approach suggested is likely to produce sufficiently low temperatures, to render the chances of success nonvanishing. Nevertheless, the project is risky, but the possibility of success offers precisely the kind of breakthrough which the low temperature community needs, and which will most benefit the LTL. The Board would like to see this project carried out at a faster rate, in order to allow the group to judge its feasibility and promise as soon as possible.

Not quite forgetting its roots, the group also intends to study the nuclear magnetism of ${}^7\text{Li}$. Here the main problem will be the preparation of a suitable sample. Given the available experimental facility, this subproject may certainly be envisaged. It is clear, however, that this experiment would not justify building the necessary infrastructure in the first place. To some extent, this program is driven by available technology.

4. Interfaces in Quantum Systems

Technically quite outstanding is also the experimental work on interfaces of quantum systems. This may actually be the branch of the Laboratory's research in low temperature physics with the brightest medium term future. The number of publications is not overwhelming but this may be related with the fact that these experiments are technically very difficult.

The study of interfaces in quantum systems using optical techniques to image liquid-solid interface upon growth and melting of crystals of both ${}^3\text{He}$ and ${}^4\text{He}$ is not a very old effort within the LTL, although well established within the broader quantum fluids and solids community. As with the vortex studies, this newer effort has also been characterised by the highest level of technical sophistication. The very recent revelation of new facets in solid ${}^3\text{He}$ upon rapid growth at 0.6 mK is quite exciting, and suggests a number of new experiments. The addition of a magnetic field should further expand the available possibilities in this area. It is hoped that the new field will be sufficiently uniform to allow the determination of magnetic sublattice orientations in the U2D2 solid and their correlation with growth facets. In addition, if fields as high as 0.5 T can be applied, one will be able to stabilize the CNAF spin ordered phase, where the magnetisation is about 60% of the saturation magnetization for the ${}^3\text{He}$ nuclear spin system. This should allow one to produce neutral buoyancy for the solid within the liquid by using very modest magnetic field gradients.

The Board indicated in its last report the view that this new avenue of research held great promise. The recent work on the growth of spin ordered solid ${}^3\text{He}$ tends to confirm this view, although much remains to be done. The goal to study how the magnetisation of the solid will modify the nature of solid melting waves is an exciting one, but we stress that this will require experimental parameters which are difficult to achieve (if at all possible), and that there are many other ways to probe how the polarisation in the solid will be manifested in the dynamics of the solid-liquid interface.

5. Mesoscopic Physics

As already mentioned the subgroup involved in the nanophysics program of the Laboratory has not yet reached the same level of international recognition, also providing the reason for attributing the status of a center of excellence, as the rest of LTL. The Board does not consider the excuse of lack of space to be the only restraint, but also the scientific program needs continuous focussing and

strengthening. Following the recommendation by the previous Board Report, Dr. P. Hakonen has been put in charge of the development in this area. In view of the undisputed scientific competence of the new group leader, the group has improved its prospects somewhat. However, in this highly competitive and rapidly developing field, the Laboratory needs a niche of research where it can be leading in the world and which can form the basis for future developments.

The suggested program contains a number of sensible projects but it is not clear in what way they are outstanding, particularly in comparison with other similar activities around the world. Most promising and innovative here seems the attempt to investigate the high frequency behaviour of mesoscopic electronic systems. Somewhat disturbing was the apparent low mood of the collaborators during the laboratory visit and some remarks made by a doctoral student after the tour. Some thoughts on novel and original technical innovations might help in this case. Much of the scientific success of the basic low temperature groups has been based on this approach. This line of action might also help to justify the required additional space for which convincing arguments cannot be based only on the present activities.

6. Brain Research Unit

The BRU is a multidisciplinary group that has been at the forefront of the field of Magnetoencephalography since more than one decade. Since the previous report, the management structure has been strengthened, and the organisation of the Unit is much improved. The activities are at an internationally excellent level, and many international cooperations are pursued. However, the administrative structure is still very closely tied to the central administration of the Low Temperature Laboratory, which may hamper the development of both the Neuroscience and the Low Temperature Research. A more focussed research program would give the Unit a clear profile and facilitate beneficial cooperation between the successful activities within the Unit.

The Unit is based on three main foundations: advanced instrumentation and software, excellent human neurophysiology and creative neuropsychology. This combination has enabled the Unit to make a series of original contributions to different fields within the Neurosciences: sensory processing, motor control, normal and abnormal language functions, and the integration of MEG/EEG/MRI. In addition the BRU has developed clinical applications of MEG and achieved important results in this field.

The Unit publishes regularly in the most important international journals in the field of the Neurosciences and in top multidisciplinary journals. Some of these publications have become classics in the field. A most prestigious contribution of the senior researchers to review journals and books of reference should also be pointed out. In the recent past a substantial number of Ph.D. theses were based on research work performed in the Unit. Members of the Unit participate actively in the most important world conferences on Neuromagnetism and related fields. Numerous collaborations with top scientists from all parts of the world have taken place and the results are clearly visible in publications. The BRU has certainly fulfilled all the criteria to be considered a Center of Excellence of international allure.

The prospects for the future of this Unit within the Neuromagnetism field are bright. The choices for the future are, in general, very adequate and promising. One major question in the next few years is to advance in merging different brain imaging modalities (MEG, EEG, fMRI). In this respect the BRU will benefit from the acquisition and installation at the same site of a fMRI facility

(see below). The plans regarding Sensory and Motor cortical functions on the one hand and Cognitive and language functions on the other, are full of exciting perspectives. The CliniMEG team has good plans for further developing clinical applications of MEG. These prospects would be even more powerful if the work on merging different brain imaging modalities mentioned above would be actively pursued as planned. The training of collaborators on fMRI and other brain imaging modalities is a welcome feature that should be actively encouraged.

It is important, however, to emphasise that the basic staff should be strengthened by giving more opportunities for senior researchers to acquire a permanent staff position.

Notwithstanding this very positive evaluation we emphasise that the Unit is at this moment at a crossroad. Briefly two questions have to be considered:

One is a question of scientific strategy: should the Unit continue to be exclusively dedicated to Neuromagnetism or should it become a more generally oriented Unit that masters also other approaches, besides MEG, that are relevant for human brain research?

The other is a question of scientific organisation: it is whether the present setting, within the Low Temperature Laboratory, is the best environment for the future development of the BRU, or would other scenarios be preferable?

Regarding the first question the answer was already indicated in the previous report of the Science Advisory Board in 1997, where it was stated that the Unit should be given the opportunity of acquiring a state-of-the-art functional Magnetic Resonance Imaging (fMRI) facility in order to expand their range of brain research tools. In the discussion that we had on June 21 and 22 it became clear that the Unit's staff is anxious to be able to get this new research tool (the BRU started an intensive training for future fMRI users in collaboration with the centers in London and Boston) and they have clear ideas regarding how to integrate the fMRI and the MEG/EEG techniques in a comprehensive way. The BRU is in a unique position to integrate the fMRI approach with their solid knowledge of electro/magnetic phenomena. Our worry is that the acquisition and installation of the fMRI unit has been much delayed. This should be given a higher priority by the responsible organisations.

With respect to the second question, we consider that the physical integration of the BRU in a Technical University with strong links to Physics and Computer science departments is an important asset. This should be acknowledged taking into consideration at the same time that the BRU should be awarded a recognisable identity. This does not only assume a well defined administrative structure, but it also presupposes certain lines of research which are identified with the BRU. In these areas the research should be substantial and outstanding on an international scale.

The setting at the Helsinki University of Technology can assure that the BRU would continue to profit from the collaboration of students and scientists of the Physics and Technology departments. In this context the BRU will be embedded in the most stimulating environment in order to continue to make important contributions to stay at the forefront of the development of neurotechniques and their application in solving important neuroscientific questions. Notwithstanding this preferred setting for the BRU, we emphasise that stronger links with clinical and neuropsychological groups on the one hand, and basic neurosciences groups on the other, would be most welcome. Thus the links to Neuroscience branches of research would be strengthened. Double appointments of scientists, participation in graduate seminars and in broad neuroscientific training programs, and

common research programs with such clinical and neuroscientific groups should be actively encouraged and pursued. This should be an essential part of the research strategy of the BRU for the near future.

7. Theory projects

The output of the theory group is outstanding but absolutely dominated by the work of G.E. Volovik. Naturally, it is great that this excellent physicist is a member of the laboratory and delivers a lot of original work. Incidentally some of it is not related with low temperature physics at all. Nevertheless, his dominance and the many publications with him as a single author is somewhat disturbing. Since the laboratory, although a so called independent research unit, is nevertheless embedded in a university, it would seem that he should be more involved in advising and guiding doctoral students.

Research related to the measurements on Helium is an essential part of the theoretical program. This is represented by both Volovik and Thuneberg. Such close collaboration between experimentalists and theorists is strongly recommended. During the laboratory tour we got the impression that the collaboration with Volovik may have deteriorated lately. If true, it should be reinforced immediately. According to the oral presentation, the role of supporting the experiments in superfluid ^3He theoretically may have shifted from Volovik to Thuneberg. In this respect, the research plan presented by Thuneberg appeared to be somewhat vague. He seems to intend to also do theoretical work for the benefit of all the other experimental enterprises, clearly an impossible if not destructive task. Although a partner with theoretical skills is very favourable for experimentalists, and Thuneberg plays this role eminently, the Board recommends that also Thuneberg develops some visions for his own work, in order to become less dependent on the output of the experimental groups and to enhance his own visibility. If the Laboratory is to support an independent theoretical group this should have some original research projects of its own. In spite of the successful support theory has given to the experimental activities in the Laboratory, the lack of leadership and coordination in the theoretical effort may lead to erratic and inefficient activity.

The other theoretical topics that Volovik intends to tackle seem somewhat detached from the experimental program. It may be that superfluid ^3He indeed can serve as a model system for studying the vacuum and its excitations. It is certainly a very stimulating possibility and the respective program deserves full support. It would be great, if talented doctoral students would be involved in it. The same remarks are true for the intended work on unconventional superconductivity, a topic that is studied in other foreign laboratories with high priority.

8. Conclusions and Recommendations

In summary, the quality of the work being pursued in the area of quantum fluids and solids is absolutely first rate, and the LTL has been able to lead the world in the topics it has chosen to study in this area. At the same time, the Laboratory needs to strike out in new directions, and it seems to the Board that they are doing so through their studies of the interface between superfluid ^3He nuclear spin ordered solid ^3He , and in their search for simultaneous boson-fermion superfluidity in ^3He - ^4He mixtures. This is clearly an effort which should be supported and pursued efficiently and as rapidly as possible.

The output of work related with experiments involving rotating ^3He is very good indeed. The available experimental facilities are probably unique in the world, which may be viewed both positively and negatively. At present the group has almost no external competitors and therefore the broad interest in the technically beautiful experiments is somewhat limited. There is little the group can do about this situation but keep doing the best possible experiments with a distinct impact on physics in general. For the reasons mentioned above, research merely investigating details should be avoided.

The publication record of the brain research section is impressive. It has produced first rate work, it is expanding into new areas, and it is well prepared to meet the challenges of the research field. As mentioned above, however, it may need to consider its future strategies and organisation carefully.

Quite excellent is the intended work on interfaces in quantum systems. It is certainly true that He crystals may serve as model systems with an impact on a broad area of physics and therefore this activity, which again demands the special skills which are available at LTL, deserves full support with highest priority. In particular the observation of crystal growth of magnetically ordered ^3He is an exciting possibility.

The publication record related with the CERN activity is at most average. It seems clear that here the laboratory does not play a major scientific role. The previous principal involvement in the SMC collaboration has come to an end with the termination of the SMC project in 1999. It is not clear, however, in which way these activities contribute to LTL as a center of excellence. Of course, LTL can provide know-how in aspects of construction of cryostats, but it is our impression that the contribution of LTL is at best marginal and as an institution it is not likely to have a decisive impact on any of the really important CERN experiments. The competence is obviously in the field of engineering rather than in basic physics. This line of research should be pursued only if it does not put any strain on the resources of personnel and space in the Laboratory. Here the overall activity of Finnish research in the CERN program should be taken into account.

As mentioned above a lot of credit for the extraordinary work in the theory group is due to G. Volovik. His present status appears to be that of a visiting professor. It may well be that names are meaningless if good work is delivered, as it certainly is. Nevertheless, it seems unusual that a considerable part of the accomplishments which qualify LTL as a center of excellence are provided by a visiting professor. We wonder whether Volovik's essential role may not somehow be reflected in his status at HUT. A change here may also induce him to take a more active part in interacting with the teaching activities of the Technical University.

If viewed from the outside, the combination of ultralow temperature physics and brain research in one center leaves an awkward impression. It is quite clear that in the past, the brain research benefited enormously from the technical and computational know-how and the scientific competence of physicists. As long as this is still true - it may very well be less so in the near future - the situation should not greatly be altered. High level performance is much more important than a lucid organisation. Nevertheless it seems also important that the brain research unit enjoys the benefits of a scientifically more adapted environment, *i.e.*, enhanced and every day contacts with biologists, biochemists and medically trained people. A convenient time for this to happen may be the announced installation of a new building in 2004. This, however, should be delegated to the administrative

organs of HUT, where the organisational problems should be considered in the view of the total situation.

As far as we know, LTL has also been given the status of a European user facility for research at very low temperatures. There was very little if any mentioning of this fact during the site visit. Is this program almost negligible for LTL's activities? If not, how does it interfere with the program presented to the Board? In view of the limited number of experimental units and considering the usually rather involved technical aspects of experiments in the millikelvin range, this interference might indeed be non negligible.

We summarise the main recommendations we have made:

1. The work on rotating Helium is at the forefront of the research in the field but it seems to have reached its point of diminishing return. If it is to be continued, the innovative suggestions put forward have to be implemented and pursued vigorously.
2. The work on the nuclear ordering has to be cut down and the possibility to observe superfluidity in Helium mixtures has to be pursued and implemented vigorously.
3. The work on interfaces is both novel, innovative and potentially very rewarding. This has to be supported and given sufficiently attention to realise its potentialities. In an intermediate time perspective it holds great promises.
4. The mesoscopic work is of great international interest and potential utility. It works, however, in an atmosphere of strong competition and rapid development. To survive it has to be more strongly supported both materially and scientifically. A suitable technological niche has to be found, and appropriate theoretical support needs to be organised, in the Laboratory or outside.
5. The Brain Research Unit is in a critical phase of development. It needs to consolidate its outstanding position in the field of the Neurosciences and employ its potential to make notable contributions to new scientific challenges. The management structure needs to be reassessed. At present, too much of the administration rests on the shoulders of the director of the Low Temperature Laboratory, who, however, is not an expert on brain research, and thus has to carry out this task in detriment of his other tasks in the field of physics where his competence lies. In due time the Brain Research Unit may evolve separately from the Low Temperature Laboratory in order to be able to grow to its full potential. This can still be organised within the highly beneficial environment of the Technical University. The most propitious time for such a separation would probably be the moment when the Laboratory will have to move to a new building.
6. The theoretical collaborations have worked well within ad hoc agreements, but in the long run this situation is less than satisfactory. The long time roles of Thuneberg and Volovik need to be evaluated, and an organisational model should be found which also supplies theoretical support to other fields of activity than the Helium research.