QANU Research Review Physics

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FOREWORD

This report follows the Standard Evaluation Protocol 2009-2015 (SEP) for Research Assessment in the Netherlands that was developed by VSNU, KNAW and NWO. The purpose of this report is to present a reliable picture of the research activities submitted for this review and to give feedback on the research management and quality assurance.

The review Committee was supported by QANU (Quality Assurance Netherlands Universities). QANU aims to ensure compliance with the SEP in all aspects and to produce independent assessment reports with peer review committees of international experts in the academic fields involved.

QANU wishes to thank the chairpersons and members of the review Committee for their participation in this assessment and for the dedication with which they carried out this task.

We also thank the staff of the units under review for their carefully prepared documentation and for their co-operation during the assessment.

Quality Assurance Netherlands Universities

Mr. Chris J. Peels
Director

Dr. Jan G.F. Veldhuis
Chairman of the Board

PREFACE

The present evaluation report is the result of a constructive interaction between the staff at the universities and the committee members. The evaluation documents and the site visits enabled the committee to perform its task efficiently. The committee thanks the institutes and programme leaders for their self-evaluations and for very interesting site visits. I thank all involved for their professional attitude and perseverance during the review process. The chairs of the three subcommittees (Hilbert von Löhneysen, Friedrich Wagner and Sanjoy Banerjee) and the committee members all showed great dedication and flexibility. Their expertise is at the core of this review.

Three subcommittees covered all institutes and programmes with parallel site visits within just one week. Clearly this was a compromise and an experiment. It worked out well, thanks to the concentrated efforts during that week, and thanks to the careful preparations and the time that was spent after the visits for writing the drafts and answering the faculty comments. The essential support by QANU (Roel Bennink c.s.) throughout the evaluation is greatly appreciated.

I trust that the efforts of all involved in this review will contribute to a clear and convincing image of the quality of physics research in the Netherlands and to its further successes in the interest of society.

J. Friso van der Veen
Chairman of the Review Committee

1. THE REVIEW COMMITTEE AND REVIEW PROCEDURES

Scope of the assessment
The Committee was asked to perform an assessment of the research in Physics at the University of Groningen (RUG), University of Twente (UT), Radboud University Nijmegen (RU), Eindhoven University of Technology (TUE), University of Amsterdam (UvA), VU University Amsterdam (VU), Utrecht University (UU), Delft University of Technology (TUD), and Leiden University (LEI). This assessment covers the research in the period 2001 - 2009.

In accordance with the Standard Evaluation Protocol 2009-2015 for Research Assessment in the Netherlands (SEP), the Committee's tasks were to assess the quality of the institutes and the research programmes on the basis of the information provided by the institutes and through interviews with the management and the research leaders, and to advise how this quality might be improved.

Composition of the Committee
The composition of the Committee was as follows:

1. Subcommittee for Groningen, Twente, Nijmegen (RUG, UT, RU)

- Hilbert von Löhneysen, Universität Karlsruhe (TH), subcommittee chair
- Masao Doi, The University of Tokyo
- Monika Ritsch-Marte, Medical University of Innsbruck
- Friso van der Veen, ETH Zurich
- Albrecht Wagner, University of Hamburg

2. Subcommittee for Eindhoven, Amsterdam (TUE, UvA, VU)

- Friedrich Wagner, Max-Planck-Institute of Plasma Physics, subcommittee chair
- Siegfried Bethke, Max Planck Institut für Physik
- Phil Bucksbaum, Stanford University
- Paul Chaikin, New York University
- Jean-Louis Martin, École Polytechnique
- Martin Stutzmann, TU München

3. Subcommittee for Utrecht, Delft, Leiden (UU, TUD, LEI)

- Sanjoy Banerjee, City University of New York (CUNY), subcommittee chair
- John Brady, California Institute of Technology
- Jonathan Richard Ellis, King's College London
- Rob Hartman, ASML, Eindhoven.
- Jürgen Kurths, Humboldt University of Berlin
- Gerhard Rempe, Technical University of Munich
- Erio Tosatti, International School for Advanced Studies (SISSA), Trieste.

Prof. Friso van der Veen acted as chairman of the Committee.

A short profile of the members of the Committee is provided in Appendix 2.

Roel Bennink of the Bureau of QANU (Quality Assurance Netherlands Universities) was appointed secretary to the Committee, with Barbara van Balen and Trees Graas as co-secretaries.

Independence
All members of the Committee signed a statement of independence to safeguard that they would assess the quality of the Institutes and research programmes in an unbiased and independent way. Any existing personal or professional relationships between Committee members and programmes under review were reported and discussed in the committee meeting. The Committee concluded that there were no unacceptable relations or dependencies and that there was no specific risk in terms of bias or undue influence.

Data provided to the Committee
The Committee has received detailed documentation consisting of the following parts:
1. Self-evaluation reports of the units under review, including all the information required by the Standard Evaluation Protocol (SEP), with appendices;
2. Copies of three key publications per research programme;
3. Results of the bibliometric study carried out by the Centre for Science and Technology Studies (CWTS).

Procedures followed by the Committee
The Committee proceeded according to the Standard Evaluation Protocol (SEP). Prior to the Committee meeting, each programme was assigned to two reviewers, who independently formulated a preliminary assessment. The final assessments are based on the documentation provided by the Institutes, the key publications and the interviews with the management and with the leaders of the programmes. The interviews took place on 28-30 June 2011 on location at the Institutes, in parallel with three subcommittees. On Monday 27 June, the Committee was briefed by QANU about research assessment according to SEP, and the Committee discussed the preliminary assessments. The Committee also agreed upon procedural matters and aspects of the assessment.

Also on Monday 27 June, the Institutes presented themselves in a series of presentations, followed by questions from the Committee. On Friday 1 July, after the site visits, the Committee convened in Utrecht to calibrate the scores of the subcommittees and to agree on the main recommendations. In the afternoon a special meeting with the rector magnificus of Utrecht University was organised, to discuss the background of the very recently announced plans for refocusing.

The texts for the committee report were finalised through email exchanges. The final version was presented to the faculties for factual corrections and comments. The final report was presented to the boards of the participating universities and was printed after their formal acceptance of the report.

The Committee used the rating system of the Standard Evaluation Protocol (SEP). The meaning of the scores is described in Appendix 1.

2. GENERAL REMARKS

Introduction

Physics in the Netherlands is in excellent shape. Bibliometric studies by CWTS show that Physics at Dutch universities is a factor 1.8 above world average as regards both the number of citations per paper and the number of highly cited papers. Physics shares these high scores with Chemistry, and the Netherlands ranks in both disciplines number two among nations worldwide. The Committee saw the international visibility and high quality of Physics fully confirmed in their evaluation. Physics in the Netherlands builds on a long and rich tradition. Physics groups continue to attract young talented scientists and profit from an excellent technical infrastructure.

The evaluation encompassed all Physics programmes in the Netherlands, thus enabling comparison between institutes and programmes at different universities. The Committee found governance practices at the institutes generally well-developed, providing a stimulating environment for scientists. Personal research awards such as the NWO funded VENI, VIDI and VIDI fellowships and ERC grants play a crucial role here. Programmes such as the Rosalind Franklin programme in RUG enable qualified women to start a career in science and are perfect instruments to promote gender equality.

A number of the institutes evaluated are of a multidisciplinary character. The Committee, having been asked to evaluate only the Physics programmes in such institutes, occasionally felt that more justice to the multidisciplinary approach would be done if the scope of evaluation in such cases would be widened.

The Committee was informed about the Sector Plan Chemistry and Physics and its beneficial role in concentrating activities, avoiding duplication of efforts and fostering collaborations between different groups. Concentration of efforts and sharing of resources are since long common practice in Particle Physics, where in the Netherlands Nikhef plays a pivotal role. The Committee noticed already existing coordination in teaching and research between LEI and TUD, UvA and VU, and RUG, UT and RU. The Sector Plan rewards this type of coordination through a number of extra positions in strategic areas.

Overview of the evaluation results

Quality
The average score for quality of the programmes is 4.6. No university has less than 4 as the average score for the quality of the programmes. Twenty-two programmes were rated excellent for quality (5), five are very good to excellent (4.5) and thirteen programmes were rated very good (4). Our findings are by and large consistent with the outcome of the citation analysis by CWTS. Where deviations occur, the Committee has taken other factors into account such as applied research or instrumentation projects whose results are generally published in a field journal or patented instead of being published in a high-impact journal. For these factors to be properly taken into consideration, the Committee found the site-visits to be of essential importance.

Productivity
Publications statistics were presented for each programme, normalized to the number of staff. The normalization does justice to the groups that publish less because of smaller size. The Committee has noted a trend toward forming smaller research groups; they are generally started by independent young scientists on tenure-track positions. 'Focus and mass' can still be achieved by having these groups work together and share resources. This governance structure proves to

be effective in scientific output and quality assurance.

Relevance
Societal relevance in this review covers three types of activities (in accordance with SEP):

- productive interaction between researchers and stakeholders (professionals, politicians, interest groups, patient organisations, environmentalists, etc.)
- valorisation (or value creation, especially in the economic sense) via spin-offs, patents, processes, etc.
- outreach activities aimed at the general public (media appearances, books, campaigns, open days, public lectures, etc.)

The SEP criteria for Societal relevance are broadly defined, including not only economic but also social and cultural aspects. The Committee has noticed that the notion of societal relevance of research at universities is still surrounded by some controversy and confusion. We believe that the self-assessment reports could have contained more detailed information on results that were evidently beneficial to industry and have led to new or improved products and processes.

The issue of relevance eventually revolves around the question: 'what is the role of Physics in society?' Although there is probably no unique answer to this question, it is a fact that much of the technology surrounding us has its roots in fundamental Physics and Chemistry discoveries. The preferred role of physicists therefore is not only to advance the discipline itself and to train highly qualified scientists, but also to directly contribute to technological innovations. The Committee has seen great examples of 'valorisation', but some Committee members wonder how strategic choices on applied Physics programmes in the Netherlands are made, how the roles of national funding agencies and applied research institutes (FOM, STW, Agentschap NL, TNO) are coordinated and what is expected from the universities.

Viability
The strength and the potential of the programmes for the future gave on average for the forty programmes that were assessed a very good score of 4.6. A threatening factor is the generally decreasing baseline (first-party) funding during the evaluation period, which most groups have so far compensated by obtaining increased funding from other sources (FOM, Agentschap NL). Given the funding uncertainties at present, the Committee has not taken this potential threat into account in the programme scores for viability.

The Committee is concerned about the viability of large facilities in the Netherlands (e.g. KVI, HMFL). The potential of these facilities and of its well-trained operational staff is not fully exploited. Clear guidance and perspectives should be given by NWO and FOM as regards investments in new facilities and their sustained operation. For lack of a national centre providing a permanent technical infrastructure, universities take up the role of host, but their long-term commitments are unclear.

7A. INSTITUTE LEVEL - University of Amsterdam

University: University of Amsterdam
Faculty: Faculty of Science (FNWI)

1. The institute
The mission of the Institute of Physics at the University of Amsterdam (IoP-UvA) is to carry out excellent research in the field of experimental and theoretical physics, to provide inspiring teaching within the physics and other curricula and to transfer their knowledge and enthusiasm into society, both in the form of collaboration with industrial partners as well as in terms of boosting interest in physics in general and in its study in particular.

The IoP comprises three research divisions, which in the period up to 2010 were independent research institutes within the Faculty of Science (FNWI) of the UvA:

- the Van der Waals Zeeman Institute for Experimental Physics (WZI), director: Prof. M.S.Golden
- the Institute for Theoretical Physics Amsterdam (ITFA), director: Prof. K. Schoutens
- the Institute for High Energy Physics (IHEF), director: Prof. S. Bentvelsen.

From January 1st 2011 these three formally united into a single IoP-UvA. The constituent divisions maintain their independent position in their respective fields of expertise, but work together in matters that concern all of Physics at the UvA. The IoP is led by a board consisting of the three division leaders. Since the summer of 2010, ITFA and WZI are housed in the new FNWI building in Science Park Amsterdam. IHEF is in the Nikhef building, on the other side of the road.

Spearhead discussions in the FNWI and nationally in the context of the Sectorplan have led to a sharply defined research and investment agenda, which is coordinated with the research at the VU and nationwide. The IoP research has the following focus areas:

- Astroparticle Physics and Gravitation (programmes UvA 4 and 6)
- Quantum Matter and Quantum Information (programmes UvA 1, 3 and 5)
- Complex Systems, Liquids and Matter (programme UvA 2 and 5).

The IoP's research themes are strongly tied to the three leading tracks in the MSc Physics degree programme: Particle and Astro-Particle Physics, Theoretical Physics and Advanced Energy and Matter Physics (AMEP).

The ITFA also maintains a programme on the History of Physics (Prof. A.J. Kox), which is not included in the 2011 research evaluation.

The particle and astroparticle physics programme at IHEF is fully integrated in Nikhef, the National Institute for Subatomic Physics. The integration is both scientific and financial, which makes it somewhat arbitrary to distinguish between the contributions of IHEF and Nikhef. The partnership Nikhef constitutes FOM with four universities (Nijmegen, Utrecht, Amsterdam UvA and Amsterdam VU).

Assessment/remarks
The move to the new building and locations seems to be quite successfully fostering more communication and collaboration between the different faculty members, students and groups.

The university should continue to recognise and actively support the symbiotic relationship between the Particle Physics groups (UvA 4 and 6) and Nikhef.

2. Quality and academic reputation
The self-assessment report gives an extensive list of high-profile publications, major research grants, programmes with IoP leadership or participation, prizes, awards, editorships and memberships. These elements are taken into account in the programme assessments.

The following personal grants are mentioned:

- Spinoza prize R.H. Dijkgraaf (2003). Volume M€ 1.5.
- Spinoza prize E. Verlinde (2011).
- ERC Advanced Grant E. Verlinde (2010). Volume M€ 2.0.
- VICI grants (ca. M€ 1.3 each): S. Bentvelsen (2006), K. Skenderis (2008), P. de Jong (2009), J.-S. Caux (2010)
- VIDI grants (ca. k€ 630 each): N. J. van Druten (2002-2007), K.E. Schalm (2005), M.M. Taylor (2005), A.P. Colijn (2005), P. Schall (2006), I. van Vulpen (2006), C. Castelnovo (2010)
- FOM Springplank fellowship J.-S. Caux (2003-2007). Volume ca. k€ 200.
- Vernieuwingsimpuls (oude stijl) K. Skenderis (2002-2007). Volume k€ 448.

Assessment/remarks
The quality of the UvA programmes under review was assessed as very good to excellent.

3. Resources
The self-assessment report states that the IoP has a clear and healthy financial medium-term future, in terms of direct funding, based on its excellent performance, proactive role in instigating attractive spearhead proposals and sound financial governance over the last 6 years. This is expected to provide the basis for continuation and extension of its success in attracting external funding. The spread of themes from fundamental (quantum universe/quantum matter themes) through to applied (soft condensed matter and energy) also means the IoP is able to make use of the full breadth of funding possibilities.

The facilities and infrastructure feature a new 'single-site' building, enabling interaction with related disciplines (astronomy, maths, chemistry). The strategic location in the Science Park Amsterdam also stimulates links with national institutes (Nikhef, CWI, AMOLF).

The FNWI MacGillavry programme, together with gender specific measures offered by the SNS-sectorplan, offers opportunities for attracting female staff members.

Assessment/remarks
The new lab facilities are very good and in some cases a significant improvement over the previous labs.

The FNWI MacGillavry programme is dedicated to increasing the number of women in the faculty. Such efforts are highly commendable.

4. Productivity
The results of the CWTS-analysis show that the UvA programmes under review have produced 1241 articles in Web of Science journals in the 4 years of the review period. These articles were cited 14181 times, not counting self-citations. The mean citation score is 5.25 for Hard

Condensed Matter, 11.7 for Soft Condensed Matter, 29.52 for Quantum Gases and Quantum Information, 11.2 for Particle Physics, Cosmology and Quantum Gravity, 8.16 for Quantum Matter and Complex Systems, and 11.63 for Particle and Astroparticle Physics. The highest number of papers among the 10% most frequently cited papers is 79 for Particle and Astroparticle Physics. The number of articles per full-time equivalent of academic staff ranges from 0.8 to 5.4 in the UvA programmes under review, with an average of 2.5. The average output per fte in all the programmes in this Physics review is 1.9.

Assessment/remarks
The productivity of the UvA programmes under review was assessed as very good to excellent, with the exception of the programme Quantum Gases & Quantum Information, which was assessed as good.

5. Societal Relevance
The self-assessment report lists an impressive array of activities that are aimed at contributing to the awareness and appreciation in society of the natural sciences and of physics in particular. These include media productions, public lessons, books, events at the NEMO science museum, outreach to teachers and even theatre plays and movies. Just one example is the `betacanon', which received important contributions from Bais, Dijkgraaf and from a number of Physics PhD students at the UvA.

Valorisation activities include joint research or industrial partnerships with Shell, DPI, Unilever, ECN, Michelin, ASML and SKF. Successful transfer of lab technology was realised to the aviation industry (ultrasonic verification alarm) and to SPECS Nanotechnology Delft (UHV-cryomanipulator) with several partners.

Assessment/remarks
The Committee found the outreach efforts and the valorisation activities very well-defined and successful.

6. Strategy for the future
The IoP is currently major player in three research initiatives within the FNWI:

- *Gravity and Astroparticle Physics* (GRAPPA)
- *Quantum Matter and Quantum Information* (QM/QI) and
- *Soft Matter.*

The GRAPPA centre has already been granted the status of a UvA Centre of Excellence, and as such it receives generous financial support from the FNWI and UvA's CvB. GRAPPA is an initiative going beyond the bounds of the IoP. It includes a group from the UvA Anton Pannekoek Institute (API) for astronomy and clearly benefits from the proximity of Nikhef and of the international particle physics consortia, especially at CERN, that the Nikhef is part of. The GRAPPA theme is increasingly important in the MSc education: GRAPPA `study-paths' will be on offer in a number of tracks within the MSc programmes `Physics' and `Astronomy'.

The IoP is also playing a key role in the synthesis of a new spearhead proposal: Quantum Matter / Quantum Information. This involves theory (programme UvA 5) and experimental (programmes UvA 3 and 1) groups within IoP, together with groups at the Centre for Mathematics and Informatics (CWI) in the Science Park. Members of the Quantum Geometry group from the maths institute in the FNWI are also expressing an interest in affiliating to the QM/QI initiative. This spearhead involves research into quantum information as can be realised

in novel quantum gas and topological insulator systems, coupled to theoretical expertise as regards entanglement theory and the physics of topological states. QM/QI maps perfectly onto the SNS-sectorplan national spearhead of the same name centred on the UvA physics institute.

A third spearhead *in spe* is Soft Matter, bringing together experimentalists (programme UvA 2) and theoreticians (programme UvA 5) from IoP, with computational and experimental scientists from the chemistry institute HIMS and from AMOLF.

Finally, Amsterdam is a fertile environment for the energy-related research of the experimentalists (programme UvA 1), with the VU, UvA chemistry and AMOLF as important and visible partners.

Assessment/remarks
The Committee fully supports the well-defined strategic direction and focus. They seem to provide a good basis for a number of succession decisions that will have to be taken in the near future.

7. PhD Training
Each of the three IoP divisions (ITFA, WZI, IHEF) has their own channels for PhD education. ITFA's main channel is via the Dutch Research School for Theoretical Physics (DRSTP). WZI uses PhD schools organised by Intercan and by large scale facilities (Hercules, PSI schools, etc.). IHEF's PhD training takes place within the national research school on subatomic physics (OSAF).

About 80% of the PhD students within IoP are either FOM employees and about 20% are employed by UvA. Both organisations have an established system of training & supervisory plans and annual progress reviews. FOM PhD employees have access to transferrable skills training (Dutch, time management & planning, career orientation) and the best practices built up by FOM over the years are a good inspiration for the UvA as employer of the NWO/EU funded PhD's which fall under her HRM remit.

Overall, some 18% of the PhD students finish within 4 years, while 62% obtain their PhD within 5 years. Only 4 out of 77 PhD projects have been discontinued.

In the coming period, the Amsterdam Graduate School of Science (AGSS) - which is a joint venture with the VU - should begin to take shape. This is expected to provide a good basis for high-quality transferrable skills training, careers guidance and quality control, complementary to the activities of the national research schools.

Assessment/remarks
PhD-students are very satisfied with their overall situation at UvA, however there were complaints about the - apparently, for students - very limited service and access possibilities for personal laptops. Terminal pools are space consuming, possibly inconvenient and seemingly outdated.

Soft Matter (UvA 2) organizes national meetings every few months and hosts a national website. Condensed Matter (UvA 1, 3, 5) and High Energy Theory (UvA 4, 6) also have lively traditions of national meetings. The PhD council of the Dutch Research School for Theoretical Physics organizes an annual PhD-day. Such efforts should be encouraged and supported.

7B. PROGRAMME LEVEL - University of Amsterdam

Programme UvA 1: **Hard Condensed Matter**
Programme director: Prof. M.S. Golden
Research staff 2009: 10 fte

Assessments:		
	Quality:	4
	Productivity:	4
	Relevance:	4
	Viability:	4.5

The programme concentrates on the electronic and optoelectronic properties of novel solid systems and has two research lines: quantum electron matter (QEM) and optoelectronic / nanophotonic materials. QEM studies the fundamental properties of correlated electron materials. Research highlights are new ferromagnetic superconductors as well as the systematic electronic structure characterisation of iron pnictide and conventional high Tc superconductors with advanced spectroscopic methods in real space and in reciprocal space. In the semiconductor-related work, silicon-based and other quantum dot systems are used to tune and manipulate optical and optoelectronic properties for fundamental photovoltaic energy research.

Quality
This group is among the leaders in the Netherlands in its specific field of research, and is well known, often invited to or active in organizing international conferences, but in the period under review not yet leading internationally. The group members have published a good number of outstanding publications in the best journals of the field (Nature, Phys. Rev. Lett.) and pursue the laudable policy of trying to produce fewer but better publications.

Productivity
The productivity of the programme in terms of papers is very high, but continuously decreasing since 2004. Part of this is probably due to the mentioned "postdoc gap" from 2006 – 2008, which has not been explained but taken care of in the meantime. The ability to attract external funding is sufficient to maintain the current level of research activities, but lacks highlights which would be visible beyond the Dutch borders and would allow the group to make a major step forward in terms of equipment and/or personnel.

Relevance
The group has contributed appropriately to University and national outreach, educational and recruiting activities. Several promising contacts with local or European industry exist for the industrial valorisation of some of the fundamental research results. The university's Knowledge Transfer Office (BKT) is involved in most cases and the group has a clear IP strategy. The photovoltaics-related research has general relevance for the future energy programmes in the Netherlands and in Europe.

Viability
The research topics covered in this programme remain at the forefront of research in hard condensed matter and, thus, can count on many more years of basic research to be funded. The group has made a lot of postdoc appointments in the recent past and, thus, is well positioned for the near future. An important issue remains the succession of Prof. Gregorkiewicz, which is currently discussed in the faculty. Here, an important decision has to be made between a further concentration of the research activities in this programme or trying to maintain a fairly broad

activity spanning metals, semiconductors and dielectrics. The recommendation of the review panel is in favour of the latter.

Programme UvA 2: **Soft Condensed Matter**
Programme director: Prof. D. Bonn
Research staff 2009: 11 fte

Assessments:	Quality:	5
	Productivity:	5
	Relevance:	5
	Viability:	5

The research focuses on soft mesoscopic materials, also known as complex fluids. Examples of such systems are colloids, emulsions, polymers, surfactants. The behaviour of complex systems arises from a multiplicity of simultaneous interactions between many particles or molecules. The research on the key issues is carried out in collaboration with other groups:

- Collective behaviour in water: with Amolf and HIMS
- Cooperative behaviour and kinetics of aggregation in systems with complex interactions: with HIMS
- Collective behaviour and mechanical properties of compacted granular and glassy systems: with ITFA and HIMS.

The Van der Waals–Zeeman lab at UvA has been well known in the field of colloids and soft matter physics before suffering from departures and retirements. Within the period covered by this review the soft matter group has been completely rejuvenated with the addition of several "young" tenured and tenure track positions. Their interests span a wide swath of the field but of course not its entirety. Although many systems are studied, there is a focus on elasticity and rheology of soft systems especially in the presence of disorder. There are plenty of applications for this research, from food to oil recovery, to granular flow, but there is also an outstanding fundamental physics question: how can a disordered material be rigid? We know that a crystal must be rigid because its broken translational and rotational symmetry mandates elastic constants. A disordered system without broken symmetry needs a different and as yet unknown reason to be rigid. Thus the problem of glasses, yield stress fluids and sands, the meat and potatoes of this group's research, attacks a basic physics problem head on. Experimentally their strength lies in microscopy and scattering, the pillars of the field.

Quality
This group in collaboration with Dave Weitz' group at Harvard have taken a leading role in the study of colloidal glasses. They have an internationally leading presence in the field of multiple scattering of waves (optical, acoustic, elastic, electromagnetic) from multiple sources, with interaction and support from the oil industry. They are a top group in rheology (elastic and viscous responses) especially in thixotropic fluids and quicksand, materials whose resistance to flow is not only stress and frequency dependent but history dependent as well. A breakthrough was the idea that aging and reparation of bonds is responsible for the behaviour of many such materials. These studies address yet another fundamental problem, the crossover from a dense suspension of particles, interacting viscously, to a slurry where particles touch and interact by friction. The group has also perfected new tools for studying materials on the micron to millimeter scale, Magnetic Resonance Imaging for studying the structures and dynamics of granular material, analysis of Confocal Microscopy for colloidal system and coupled seismic-electromagnetic sensing and correlation techniques for composite materials and the oil industry. While many groups are studying critical Casimir forces, here there are beautiful experiments making use of the critical Casimir forces to programme and control the interactions between colloidal particles.

Productivity
This relatively small group has succeeded to place many publications in high profile journals such as Physical Review Letters, Nature and Science. Moreover, the committee was particularly impressed by the fact that, in addition, this group has followed up such preliminary research reports by substantial longer original papers and review articles.

Relevance
The group produces a growing number of graduate students trained in modern techniques relevant to both fundamental science and industry. There is an impressive outreach programme with popular demonstrations for the public. An example is the shear thickening cornstarch bath where students and the public can run across a bath of cornstarch in which they would sink if slowing walking. There are strong interactions with industry to the extent that several of the students have support from industry or are employed by industry and sent to get their advanced degrees with this group. According to the tenured staff there is so much offer of industrial support that most of it is rejected and only the projects with the most interesting science are pursued.

Viability
This is a young energetic group with evident internal and external, national and international academic and industrial collaborations. The group is still growing in reputation and number of students. The group is small and will benefit from the addition of an equal quality tenure track position.

Programme UvA 3: **Quantum Gases & Quantum Information**
Programme director: Prof. J.T.M. Walraven
Research staff 2009: 8.2 fte

Assessments:		
	Quality:	5
	Productivity:	3
	Relevance:	3.5
	Viability:	3

The group explores novel quantum few-body and many-body phenomena with ultracold atoms, both experimentally and theoretically. Important aspects are the role of quantum statistics, dimensionality, many-particle entanglement and decoherence, and quantum simulation of open problems inspired by condensed-matter, nuclear and astrophysics. There are two main themes:

- novel regimes of strong interaction in quantum gases. The research focuses on mixtures of quantum gases and long-range interactions induced by Feshbach resonances. The aim is to influence pairing, trimer-formation and many-body phenomena. Tuneable interactions can also be realized in one-dimensional (1D) bosonic quantum gases by confinement in atomic waveguide structures. This enables comparison with exact theory (thermodynamic Bethe Ansatz) and the investigation of novel forms of spin dynamics.
- the use of coherent interaction between cold atoms. They investigate ways to develop a quantum simulation and quantum information science platform, where information is stored in hyperfine ground states but processed using Rydberg states.

The Van der Waals–Zeeman lab at UvA has a long and excellent tradition in atomic physics. The present group whose focus has changed to cold atoms in controllable condensates for basic understanding of interacting systems and laying the foundations for quantum information has continued this tradition. Individually their accomplishments are equal to any but at present they don't have a big enough group to be competitive with institutes that have been set up in other countries. Presently the Netherlands has not emphasized quantum gases as a priority research area and the group therefore must look to EU funding to continue. The group has been active with collaborations and joint grants with the UvA theory institute and for fabrication with the nanocenter partnered with Amolf.

The fundamental aspects of the research have been quite successful with experiments on Feshbach resonances in cold two particle mixtures of fermion gases and Efimov states (bound trimers, where pairs are unbound). There have been interesting studies of cold atoms on surfaces, chips, and novel patterned magnetic arrays used as traps and shift registers for possible use in quantum computing. The 1/5 position of Shlyapnikov has been very helpful for theoretical support and collaboration and has produced some exciting theory.

The transition from the old lab to the new building was difficult but according to the group it is an enormous step forward in having the labs close together and for fostering collaborations internally and with the theory group.

The magnetic chip work of Spreeuw and Van Druten is excellent and could constitute the real future for this group. Parts of the group seemed to have suffered from long-time absences and approaching retirements.

Quality
The quality of the research of this group is exceptional. The group is small but in general has better, more original ideas than its competitors. There is a nice balance between the fundamental work and developments that might be used in applications to quantum information.

Productivity
The Committee viewed the productivity of this group as low in comparison with the other experimental groups that we rated, in spite of the reasonably high bibliometric figures. They have a lower number of PhD students and postdocs with respect to the 5 faculty members than comparable groups. The number of postdocs has dropped from a respectable ~6 in 2004 to ~1 in 2009, but the number is now back up to 5. The total number of refereed publications in 2009 was only 8, well below what such a group is capable of.

Part of productivity is producing new funds in the form of FOM grants. Here we note that the long-term funding, headed by Walraven, seems about to run out in 2011. The appointment of a new professor in the team offers an opportunity to initiate a new FOM programme.

Relevance
The work of this group is primarily fundamental, but presently there are relevant applications in terms of perfecting time keeping with atomic clocks, precision frequency measurements and GPS navigation. It is not clear that the group is making contributions to applications in these areas. There are also future potential applications to quantum cryptography and computing.

Viability
A theoretical leader, Shlyapnikov, and an experimental leader, Walraven, will retire in the coming few years. The Committee felt that the preparation for these major transitions has been inadequate, with a search just commencing.

Programme UvA 4: **Particle Physics, Cosmology and Quantum Gravity**
Programme directors: Prof. E. Verlinde, Prof. E. Laenen
Research staff 2009: 17.7 fte

Assessments:		
	Quality:	5
	Productivity:	4
	Relevance:	4
	Viability:	5

The objective of this programme is to unravel the physics of Nature at its smallest and largest length scales. The fundamental nature of elementary forces, especially of Quantum Gravity, is explored from a string theory context. Gravitational physics are related with the physics of strongly interacting quantum matter through a mathematical connection known as AdS/CMT. An important research objective is to employ these new insights and study its implications for cosmology and areas of physics such as high temperature QCD and condensed matter theory. The area of Particle physics related to LHC experiments is also addressed, in part with links to Nikhef, focussing in particular on top quark physics, as well as research into Cosmology and astroparticle physics. The main theme being pursued is the issue of non-gaussian fluctuations in the CMB spectrum, which would reveal much about inflation, and the nature of Dark Matter.

Quality
The scientific activities and results of this research programme are internationally very well recognised and in fact belong, in the full range of research topics pursued, to the top-5% of comparable research efforts and results world-wide. The same is true for a number of group members who not only lead the research in these fields, string theory and particle physics phenomenology, in the Netherlands, but who belong to the leaders of their fields in Europe and the world. In string theory, new and original fields were defined e.g. with fusion rules in CFT (conformal field theory) – the Verlinde rules -, strings in black holes, the entropic formulation of gravitation, topological strings and matrix models. In particle physics phenomenology, new Monte-Carlo tools were developed that allow precise simulations of specific reactions at the Large Hadron Collider (LHC), which are widely utilised in the international effort to analyse LHC data in terms of precision tests of the Standard Model (SM) of particle physics and searches for possible new physics signals beyond. The number and broadness of results as well as their scientific quality is regarded to be outstanding. The impact of these results on other studies in similar fields, by other scientists world-wide, is regarded to be outstanding, too. The scientific success and impact of this programme is also visible from the very impressive list of prizes and funding programmes recently awarded to (members of) the group – as the Spinoza price, VIDI and VICI grants, an ERC advanced grant.

Productivity
The scientific productivity of this research programme is, in accordance with the excellent quality of the results in general, very high and also meets highest international standards. About 40 publications per year, most of them in peer-reviewed journals, 3-4 PhD theses annually, and especially the outstanding quality of these publications in general, aim for the highest marks also in productivity. The Committee, however, realised that most of the refereed articles are published in one journal only, Journal of High Energy Physics (JHEP), which has a viable impact factor of 6.0, but which is hardly known in physics branches outside of string theory and particle physics phenomenology. The Committee considered exclusive publication in a journal actually founded within this very same field to be too narrow and not to be of the very highest credibility. The Committee also recognised absence of summary and review articles about these fields, authored

by members of this programme, as another factor that led to reducing the very highest possible mark (a "5") to "4" in order to account for these deficiencies, in comparison to other groups and programmes regarded in the course of this review. The programme is considered as nationally leading, and of high international recognition.

Relevance
While being of highest relevance to the field of science, string theory and particle physics phenomenology as a whole have, in general, limited direct impact on society. This research programme has, however, very large secondary impact on societal matters through the large number of extremely well-trained and successful PhD students and post-docs, most of which actually do or will not stay in basic science but will take over positions in many fields of society. The fields of string theory and theoretical physics are known to interest and attract many young students, often the best of their age group, and therefore motivate many talented young minds for basic research and unconventional thinking in general. There is also huge public interest in the topics studied in this programme, and the group is in fact very actively engaged in public outreach programmes.

Viability
The groups engaged in this programme made a very professional, extremely motivated and dynamical impression on the board members. The size and age structure of the groups are regarded to be very healthy, as are the future plans presented to the board. Recent appointments of several world-renowned scientists with undoubted future potential, and perspectives for further appointments, secure the long-term scientific programme and excellence of the group. Several earned prizes and funding programmes, adding to about 10 M€ in total, will enable to pursue a very solid and lively science programme for the coming years. The programme is excellently networked both on the national and the international scale.

Conclusion
In total, the Committee rates this programme to be of highest international visibility, scientific quality and impact. Although being 100% knowledge- rather than application-oriented, it has very high impact also on societal and non-scientific aspects of life. The future prospects of this programme, assuming continuation of support by the university and funding sources, are regarded to be excellent without any doubt.

Programme UvA 5: **Quantum Matter and Complex Systems**
Programme directors: Prof. K. Schoutens, Prof. B. Nienhuis
Research staff 2009: 10 fte

Assessments:		
	Quality:	4
	Productivity:	4.5
	Relevance:	4
	Viability:	4

Central to this programme is the study of collective effects in quantum and classical many-body systems. The research on low dimensional quantum matter is under the direction of Kareljan Schoutens, Aad Pruisken, and Jean-Sébastien Caux. The research on complex systems and collective phenomena is directed by Bernard Nienhuis and Theo Nieuwenhuizen. The different programmes are largely collaborative, both within the Institute of Physics at UvA and also outside. The programme is integrated in the Dutch School for Theoretical Physics, as well as the Delta Institute for Theoretical Physics at Amsterdam, Leiden, and Utrecht. They also have collaborations through the ESF INSTANS programme, where again Schoutens has a leading role within the Netherlands. Other collaborations include some of the international leaders in these areas, such as David DiVincenzo from IBM and Microsoft Station Q. Collaborations within the Amsterdam IOP include multiple interactions with UvA 4, and many collaborations with all three experimental areas (UvA 1-3).

Quality
We find that taken together, this group has clear national leadership, and is internationally competitive. One measure of quality is honours and distinctions, and here the group has done quite well in the Netherlands. They have captured one VICI and two VENI grants from NWO, as well as nine FOM projects or Projectruimte. Schoutens has been elected to the Royal Society, and there are also several other awards and honours.

In the area of Quantum Matter, emphasis within this group has moved in the direction of cold atomic matter, quantum information and quantum computation. Recent topics have been (i) quantitative measures of entanglement in quantum matter (ii) the characterization of quantum critical behaviour in the quantum Hall effect (joint with programme UvA 1), and (iii) topological phases and topological quantum computation. These projects align well with the national research priority of Quantum Matter and Quantum Information.

In the area of Complex Systems, the programme studies granular and colloidal matter. Investigation into the nature of the jamming/yield transition is done in collaboration with the Soft Matter group of the WZI (programme UvA 3). This applies to a wide range of complex transport phenomena, from traffic to glasses. A new initiative tries to understand the self-organization of virus capsids. These projects align with the national research priority of Soft Matter.

High quality is demonstrated throughout the programme. Here are just a few examples that demonstrate this: J.-S. Caux has begun a VICI project on Bethe liquids, as a new way to study dynamics both in and out of equilibrium. B. Nienhuis is studying the formation and thermodynamic stability of viral capsids, and in a different collaboration he is studying dynamics properties of colloidal glasses. This is a direct measurement of free energy in dense colloidal suspensions, with relation between force chains and low frequency vibrational modes. These projects require close couplings of theory and experiments. Nieuwenhuizen has projects ranging

from multiple light scattering and the thermodynamics of glasses to fundamental "beyond the quantum" projects with UvA 4. Pruisken has taken on topological principles in the theory of Anderson localization. And K. Schoutens has made some progress on topological methods for quantum registers.

Productivity
The output of this group has been trending upward in the last year of the reporting period, with higher quality publications and excellent postdoctoral placements as important evidence of this. There was a rather substantial but temporary dip in the overall staffing and publications, reaching a low point in 2008. This was at least in part due to funding, which has now been increased through several nationally funded collaborative projects. Also, increase in activity can be connected to the arrival in 2007 of J-S Caux in the group, and his more recent VICI award. In addition, a VENI was awarded to Snoek and to Pozsgai. We further note that the choice of Quantum Matter and Quantum Information is well-positioned for resources from the Sectorplan Physics and Chemistry.

Collective quantitative productivity measures are therefore trending upward. The group has rightly noted that the number of post-docs and PhD students in the programme should be higher. A new tenure track professor will join the group in September 2011, with a particular emphasis to continue to strengthen the quantum matter and quantum information area. We feel confident, therefore, that the upward trend should continue, thus justifying a high productivity score.

The funding of this programme is interwoven with other groups in the Institute of Physics. Theory (programmes 4 and 5 are considered together in the ITFA, and it appears to be approximately equally split between tier 1 and tier 2 funding. Much of the tier 2 funding is collaborative, and contributions to UvA 5 are not separated in all cases. It is clear qualitatively that this group gets a reasonable share of the collaborative funding in the areas where it participates. ITFA as a whole has successfully competed for nine Open Competition (projectruimte) Grants at an average of 300k Euros.

Relevance
Relevance scores in this group come primarily from their excellent record of contributing materially to the success of other research groups through strategic collaboration; and a related measure, the placement of graduate students in productive roles following their tenure in the group. The research staff consists of approximately five positions, with stable student participation and rising funding. The total research staff is approximately 11 fte. This group presented its tracking of employment following the PhD as one important evidence of relevance. They point out that out of 93 PhD's in the Dutch Research School for Theoretical Physics during the review period, 65% find employment in postdoctoral academic positions, while 28% go immediately to the commercial sector or to government.

In addition, the increased visibility of the Amsterdam Summer Workshops has helped this group. They are organizers of the biennial Amsterdam Summer Workshops on *Low-D Quantum Condensed Matter* (2005, 2007, 2009).

Viability
We find that the viability of this group is quite high. The group has settled on a programme focus that is in line with several national priorities in science, and therefore should be supported in the intermediate term. In addition, the senior staff is by and large in their early to mid-career, therefore lending stability to the group. The current growth of an additional faculty member

makes this even better. Funding is growing, and the number of students should be expected to grow as well as a result. Finally, the group should be commended for their high degree of collaboration within the Institute of Physics. This not only cements relationships across the UvA programmes, but also will serve in the long run to give the UvA the best opportunity to take early and optimal advantage of opportunities close to their research expertise. We only caution that our optimistic view presupposes that the programme growth seen in the past two years can be sustained, but we believe that the group is committed to this and knows how to accomplish it.

Conclusion

This group deserves its ranking as the leaders in the Netherlands in this area. If it continues on its current upward trajectory, we are confident that it will achieve real international leadership in its chosen areas as well. Specific recommendations to achieve this include: continued efforts to strengthen the complex systems and collective phenomena focus area, through new faculty (currently a search is planned) and through the special mechanism of extraordinary professorships. Also, it is clear that the fortunes of this group depend very seriously on the level of research funds available for competitive grants.

Programme UvA 6: **Particle and Astroparticle Physics**
Programme director: Prof. S. Bentvelsen
Research staff 2009: 25.1 fte

Assessments:		
	Quality:	5
	Productivity:	5
	Relevance:	4
	Viability:	5

The research objectives for the Institute of High Energy Physics (IHEF) are the investigation of the properties of the fundamental constituents of matter and their interactions and the use of particle messengers to gain insight into high energy astrophysical processes. To accomplish this, two main directions of research are followed:

1. Experiments making use of the world's foremost accelerators in terms of centre of mass energy and luminosity. In particular, participation in the ZEUS experiment at the HERA electron-proton collider at DESY in Hamburg, participation in the D0 experiment at the Tevatron collider in the vicinity of Chicago, and participation in the ATLAS experiment at the Large Hadron Collider at CERN in Geneva. Activities of IHEF include detector construction, data analysis and development of theoretical predictions.
2. Astroparticle physics. IHEF is participating in the Antares experiment, a water Cherenkov experiment in the Mediterranean Sea, which aims to unravel astrophysical processes through the detection of neutrinos.

The research benefits from the close cooperation with the national institute for subatomic physics, Nikhef.

Quality
The scientific activities and achievements of this research programme are internationally very well recognised and compare, without doubt and in the full range of research topics pursued, very favourably to the top-5% of comparable research efforts and results world-wide. The visibility and impact of this group, and of many individual UvA scientists as well, in several international large-scale experiments and collaborations is significantly higher than their percentage of collaboration members in terms of manpower. Although these achievements are obtained within the (larger) groups of Nikhef, the board acknowledged that UvA scientists in this endeavour play a leading role in planning, designing, building and running the various projects, as is visible e.g. by the many leading positions and convenorships UvA scientists had and still have in these projects. Especially the ATLAS group plays a significant role in this multinational project. The amount and quality of forefront particle detectors and modules built and managed by this group is outstanding. The group is also strongly engaged in harvesting the fruits of these efforts through their engagement in forefront physics analyses of ATLAS and Antares data, as well as in analysing data from previous, now (or soon to be) discontinued projects like ZEUS and D0.

Productivity
The number, quality and impact of technical contributions and scientific publications out of this programme are excellent, and again compares well to the top 5% of institutions or groups of this field world-wide. While these publications are, in general, products of large international collaborations with large to even huge (e.g. in terms of ATLAS) lists of authors, the UvA group is known within these collaborations and beyond, to be strong leaders within these international endeavours. This manifests for instance in several convenorships of important physics study

groups and in many presentations of UvA scientists at international conferences, representing large international collaborations. Results are published in world-leading and recognised journals.

Relevance
The direct societal relevance of basic and knowledge-oriented research is normally very limited. In the case of the programme, significant technological advancements have been achieved in the field of developing particle detectors and read-out electronics capable of digesting highest rates and amounts of data. These developments have impact e.g. on the development of particle detectors for medical purposes like the Medipix project. As typical in this field, however, such developments are not protected by patents, but are left open and available for all kinds of scientific and commercial uses. Education and technical as well as scientific training of large numbers of PhD students and post-docs, and the impact of this human capital on society and industry, makes the societal value of this field recognisable in many fields and aspects of life. The outreach activities of this programme, documented by an impressive number of projects, are excellent and in fact hard to outperform. Altogether, the board regards the sum of these achievements, according to internally defined indicators, to be of very high international and leading national scale.

Viability
Future prospects of this programme are regarded to be of highest national and international standing, and are in fact excellent given the scientific importance, international standing and future relevance of these projects – ATLAS as well as Antares/KM3NeT . The programme is at the forefront of scientific research in both collider physics at the very highest energies, and in high energy cosmic neutrino physics. The complementarity of these programmes ensures long-lasting viability in these fields, and offers very interesting future prospects also for students and young post-docs. The age structure of this group appeared to be very favourable and extends well into the future. The team made a very motivated and dynamic impression to the board members.

Conclusion
The overall impression of this programme is excellent and of highest international standing, comparing well to the top 5% of institutions in this field world-wide. The symbiosis with Nikhef and the concentration of basically two complementary programmes in particle and astroparticle physics, together with the extreme international networking, makes this programme an extremely attractive and fruitful part of basic research and student education in the Netherlands.

8A. INSTITUTE LEVEL - VU University Amsterdam

University: VU University Amsterdam
Faculty: Faculty of Sciences (FoS)

1. The institute

The Faculty of Sciences (FoS) offers research and education in the natural sciences, mathematics and computer science. The research of FoS is organized in four Departments: Computer Sciences, Physics & Astronomy, Chemistry & Pharmaceutical Sciences, and Mathematics. In addition to this departmental structure, many research efforts within the FoS are embedded in five interdisciplinary/interfaculty research institutes: the Network Institute, Neuroscience Campus Amsterdam, the Institute for Lasers, Life and Biophotonics (LaserLAB Amsterdam), the Amsterdam Institute for Molecules, Medicines and Systems (AIMMS) and the Centre for Advanced Media Research Amsterdam (CAMeRA).

The Department of Physics and Astronomy was established in 1930. Initially its activities were focused entirely on nuclear physics. Gradually other research activities were started and the nuclear physics activities were terminated, while keeping a group in particle physics that became associated with the National Institute NIKHEF. In the 1970s and 1980s research groups in condensed matter, biophysics, astronomy, and laser physics were started. At the turn of the century it was decided to terminate activities in astronomy and start instead a new effort focusing on the life sciences: Physics of Complex Systems, with a focus on single molecule and cell-level biophysics. More recently, the VU also began a new initiative in Energy, building on parallel efforts in the Biophysics group on photosynthesis and in the Condensed Matter group on Hydrogen storage.

The department strategically positioned itself in the Sectorplan to focus on physics of life, physics of energy and physics of light and matter. All new investments will be tied to activities in life and energy science. This is in line with the major themes of the VU University as a whole, which include "Human Health and Life Sciences" and "Sustainable Earth, Energy and the Human Environment".

The research of the VU Physics Department is in its entirety embedded in two institutes: the Institute for Lasers, Life and Biophotonics (LaserLaB) and Nikhef. These institutes have their own research management, a well-equipped infrastructure and innovative capacity.

Assessment/remarks

The academic reputation of the physics institute is internationally very high, and they are well-positioned within the Netherlands to work in three of the central themes in the Sectorplan: Physics of Life, Physics of Energy, and Physics of Light and Matter. These match quite well with the local strategy of VU to emphasize "Health and Life" and "Sustainable Earth/Energy/Environment."

The Committee found good coordination with other physics institutes in the country through LaserLab Amsterdam and LaserLab Europe, where there are significant developments in metrology of use to the whole science enterprise, and the Nikhef Institute, where there are significant contributions to both VIRGO and LHC-B.

2. Quality and academic reputation

In the period 2004-09, 5 VICI grants (De Boer, Eikema, Wuite and adjunct professors Ten Wolde and Linnartz), 7 VIDIs (Wuite, Peterman, Iannuzzi, Bethlem, Kennis, Dame and adjunct

professor Koenderink), and 2 ERC grants (Bethlem and Iannuzi) were awarded to VU faculty. Van Grondelle was appointed as special KNAW-professor, with a grant to appoint a young professor in the field of photosynthesis/energy for 5 years. Both Griessen and Van Grondelle were invited to hold the prestigious Physica-lecture (only one physicist per year).

Assessment/remarks
The recruiting and the promoting of young people and development of staff, which is so critically important in a university research department, is going very well at VU. One piece of evidence for this is the extremely large number of personal VIDI and VICI grants. Just over this six year period, no fewer than three faculty members received both VIDI grants early in the period, and VICI grants towards the end. The department should take great pride in this.

3. Resources
A significant factor is the decrease in direct funding from the university of over 7% per year in 2004-2009, which has led to the virtual elimination of university-funded PhDs. This accounts for a large part of the nearly 10% decrease in total staff during the review period, much of which has been in PhD students.

The low level of direct financing will threaten the level of the existing mechanical and electronics workshops and support. The status of the Sciences building at VU-campus is becoming out-dated and poses a threat for future advanced research.

Assessment/remarks
The Committee had some complete but rapid tours, which convinced us that the Physics programme is making the very best use of some very challenging older infrastructure. The Committee was particularly taken with the large number and variety of laser installations, some of which would benefit from better environment because of the needs of precision metrology through the use of ultrastable lasers.

4. Productivity
The results of the CWTS-analysis show that the VU programmes under review have produced 893 articles in Web of Science journals in the 4 years of the review period. These articles were cited 13177 times, not counting self-citations. The mean citation score is 10.03 for Atomic and Laser Physics, 22.71 for Complex Systems, 7.63 for Condensed Matter, 13.93 for Biophysics and 15.68 for Subatomic Physics. The highest number of papers among the 10% most frequently cited papers is 54 for the group Complex Systems. The number of articles per full-time equivalent of academic staff ranges from 2.1 to 1.5 in the VU programmes under review, with an average of 1.9. This is the same as the average output per fte in all the programmes in this Physics review.

Among the high-impact output in 2004-2009, there have been 14 articles in Nature and Science, as well as over 200 in Physical Review Letters, of which approximately 80% were from the Subatomic Physics programme.

In the review period of 2004-2009 there were 15 patent applications, compared with just 2 in the previous period of 1996-2002.

Assessment/remarks
The productivity of the VU programmes under review was assessed as very good to excellent.

5. Societal Relevance
While the major aim of VU-physics is to excel in the academic arena, two staff members hold important patents in the field of biomedical optics, De Boer in Optical Coherence Tomography instrumentation and Iannuzzi in relation to his development of the "fibre-top cantilever" instrument with a number of medical applications as well. The latter is in the process of setting up a spin-off company based on his invention.

The Atomic, Molecular and Laser physics group is involved in a FOM-industrial partnership programme with companies ASML (Lithography), TNO and the Netherlands metrology institute VSL, while it is a partner in the MEMPHIS-"Smartmix" consortium (Merging photonics with electronics), funded by the ministry of economic affairs with 28 M€. Also a number of research projects are carried out for the European Space Agency in relation to future satellite projects (SCIAMACHY, ADM-Aeolus, and on length metrology). A former PhD student has started a company (OGS Systems). The "Fascination of Light" exhibition was organized in Amsterdam by LaserLaB.

Assessment/remarks
The societal relevance of the education, the valorisation efforts and the outreach activities are highly appreciated.

6. Strategy for the future
Activities in astronomy and in physics-applied computer science have been terminated, while new activities have been defined in complex systems and biomedical optics. In the near future, the existing group in "condensed matter physics" will be transformed and redirected towards "physics of energy" with a focus on photo-conversion materials. The four new positions available through the Sectorplan will be used to further strengthen research in "life" and "energy".

The department maintains a dedicated activity in particle and astro-particle physics with a high profile and successful group embedded in the structure of the national research institute NIKHEF. Key research areas are here: matter-antimatter physics at LHC-b and gravitational waves associated with VIRGO.
Over the past few years, the department of physics has shifted its hiring priorities toward a focus on identifying promising young scientists, hired increasingly in tenure-track positions. This focus on hiring younger faculty has helped to weather severe budget cuts in structural funding, as many of these recent hires have been very successful in raising research funds. This is particularly true in the case of personal fellowships, with numerous VIDI, VICI and ERC grants.

The nation-wide Sectorplan strongly emphasized complementarity between universities. In this regard, the two universities in Amsterdam were very positively viewed for their largely non-overlapping activities. The UvA has chosen, for instance, not to emphasize biophysics, a major focus of the VU. Additionally, the VU has chosen to shift increasingly away from condensed matter and materials science toward energy oriented research. Areas of continuing overlap include particle physics (with both UvA and VU efforts embedded in NIKHEF) and atomic and laser physics. Here, there has been enhanced cooperation, for instance, with several UvA groups participating in the LaserLaB, based at the VU.

The department is committed to improving the representation of women at all academic levels within the department. In 2010, Marloes Groot was promoted to full Professor, and Roberta Croce (also recipient of a VICI award in 2011) was recruited as full Professor, beginning March 2011.

The restructuring of the Physics department and its refocusing of research topics will undergo another major step during spring 2011. It has been decided to terminate activities in "classical" solid-state physics and re-direct to a programme in solar fuels. From mid 2011 there is a strong research team in Physics of Energy, focusing on BioSolar Cells and (anorganic) Solar Fuels. This team has been strengthened by a number of project grants from the Netherlands programme "Toward BioSolar Cells", by a new FOM-programme "The Thylakoid Membrane" and the ERC advanced grant of Prof. Van Grondelle. In addition a new research programme in Biomedical Imaging will be defined, concentrating the activities of De Boer (Optical Coherence Tomography), Groot (Neuroimaging), Iannuzzi (Fiber-top cantilevers) and Verdaasdonk (VU medical centre). The development of a soft-röntgenlaser (Eikema) for life science imaging is also associated with these activities.

According to the self-assessment report, the funding of the research activities is at a high level with various VU-physicists coordinating FOM programmes and a number of young VU physicists who have acquired major personal grants (ERC, VICI, VIDI). The relatively low level of influx of bachelors students into the physics programme, resulted in a low level of direct funding, but this is now largely compensated by the activities of the physics department in the bachelors programmes of Medical Natural Sciences and Science Business and Innovation, which comprise 50% and 30% physics-related courses, respectively.

The restructuring of the bachelor of physics programme into a joint activity with the University of Amsterdam, with the VU emphasizing the themes of life science and energy, is expected to help attracting a larger number of students. Still, the self-assessment report states that the low level of direct financing will threaten the level of the existing mechanical and electronics workshops and support, and that the status of the Sciences building at VU-campus is becoming out-dated and poses a threat for future advanced research.

Assessment/remarks
The Committee is very positive about the local coordination between VU and UvA. While they are maintaining their independent points of view, at the same time they engage in both joint research and joint educational programmes to the benefit of the whole country. The very recent decision to have overlapping academic programmes for the Bachelors degree is extremely positive. Harvard and MIT have been doing this for a number of years and the benefits to physics programmes are very strong.

7. PhD Training

The PhD students are mainly trained within their research groups. The training includes seminars at group meetings. In most cases they attend an international summer school in the first year. Students are encouraged to follow courses on academic skills (writing, presentations) as provided by university and FOM. In addition, theory students in all programmes are automatically part of the Dutch Research School of Theoretical Physics (DRSTP), which organizes an annual school for students in the first two years of the PhD. The DRSTP reviews the activities and progress toward the PhD on a yearly basis. Likewise, experimental particle physics students are part of Dutch Research School for Subatomic Physics (SAF), which provides similar support, supervision and training programmes.

The PhD students have generally been successful finding their way into various careers. Some graduates have found positions in industry (Philips, ASML, JPK); several are pursuing a career in consultancy (Roland Berger Strategy Consultants); many students pursue a career in academia and find postdocs at leading institutions (e.g., Imperial College, MIT, Stanford University, Princeton

University). Recent graduates from this period have already obtained excellent faculty or group leader positions.

Assessment/remarks

The Committee had a very productive visit with the students. They are quite happy, but had some suggestions about creating opportunities for them to interact with each other, across the groups. A particular suggestion was a grad-student run journal club.

8B. PROGRAMME LEVEL - VU University Amsterdam

Programme VU 1: **Atomic, Molecular and Laser Physics**
Programme directors: Prof. W. Ubachs, Prof. K.S.E. Eikema, Dr. W. Vassen, Dr. H.L. Bethlem, Prof. T.D. Visser
Research staff 2009: 13.73 fte

Assessments:		
	Quality:	5
	Productivity:	4.5
	Relevance:	4.5
	Viability:	5

The research focuses on the fundamental interaction of light and matter, on the development of advanced laser sources and on cooling, trapping, and manipulation of atoms and molecules. The programme had two subprogrammes:

- Precision metrology and manipulation of atomic scale systems: the development and use of the most precise tools of physics available today to test the current physical understanding of matter.

- Optical coherence theory and non-linear dynamics: theoretical research on the use of spatial coherence to tailor the properties of light fields and their interaction with sub-wavelength structures.

The programme is part of LaserLab Amsterdam, which itself is associated with LaserLab Europe. The main reorganization since the previous review has been to phase out the theory component, which was represented by the Visser group (now at Delft) and to concentrate the programme to contribute to the VU Focus Area of Physics of Light and matter, a main item in the University's current "Sectorplan." Bethlem has also joined the group from Berlin.

Within this broader area the group specializes in fundamental light-matter interactions, and they have identified a number of scientific targets where they can establish a world-leading position: Search for cosmic-scale variation of fundamental constants; Tests of QED in atoms and molecules; Control of atoms and molecules; ultrastable (~1 Hz) lasers; VUV frequency combs; and frequency standard distribution throughout Europe. We found that this list is appropriate, with a good balance of fundamental science and metrology, and excellent display of the group's expertise.

Quality
The quality is at the "best in the world-class" level in the area of fundamental studies where the group has decided to concentrate its efforts. The metrics support this both in paper quality and normalized citation indices, but we were also strongly influenced by our interview which delved into some of the details of the measurements. The search for variation in the fine structure constant focuses on a critical element in that determination, namely the ratio of the electron to proton mass. This can be deduced from precision spectroscopy on states in molecular hydrogen and its isotopes, done in the laboratory and also compared to astrophysical observations of deep space. The group has come up with a novel and potentially much more sensitive test based on transitions in methyl alcohol that are exponentially sensitive to the proton mass, which could be a game changer in this field.

This group is particularly strong because it can draw different expertise from the different senior staff, and combine them in new ways. A particular example of this is the combination of UV metrology and cold molecular fountains. We observe that the current precision of less than one part per billion, which is already competitive in the measurements of the proton-electron mass ratio, stands to be improved substantially in this lab.

Other similar examples of world-leading activities include the frequency combs in the extreme ultraviolet, where the group has developed a unique new method based on OPCPA that can increase the spectral brightness of these sources substantially while maintaining their spectral precision. Yet another example is the development of degenerate quantum gases of both metastable ^{4}He* (a boson) and ^{3}He* (a fermion).
The group demonstrated spectacular Hanbury-Brown and Twiss-type measurements showing how the statistics lead to dramatically different behaviour at low temperature. This then leads to the ability to make world-class measurements of the nuclear size through optical spectroscopy at the part per trillion level. This is truly outstanding work, with both high visibility and high impact.

Bethlem has both VIDI and ERC funding and has focused on precision measurements in cold molecules using the Stark deceleration methods that he has developed previously in Berlin.

Productivity
This group has very high productivity, which must be considered in the context of the precision measurement community, which always emphasizes quality over quantity. Their absolute productivity metrics with regard to papers therefore place them more in the middle of the Physics programmes that we reviewed rather than at the absolute top. However, we argue that their productivity is much higher than this, hence the 4.5 ranking. There are no weak examples among the four subprogrammes of the senior staff. The number of papers per fte is only 1.5, but those papers have such a high impact that the normalized citation index (MNCS) of 1.77 places them far above the norm of excellence in their field. Other elements of high productivity include the steady production of both papers and students; a marked expansion of activities that all relate to their expertise in fundamental measurements.

Relevance
Traditionally groups that focus on precision measurements of fundamental constants and symmetries have a more difficult time demonstrating near-term societal relevance, but this group is an exception: we determine that the relevance factor is extremely high, nearly at the top grade. The reason is that there is an appropriate large emphasis on the development of advanced laser techniques and sources of control; and the group has found a mode of operation where it can easily and naturally export this very specialized knowledge to applied projects and problems throughout the Netherlands and Europe. External links are made easier by the embedding in LaserLab Amsterdam, LaserLab Europe, as well as a number of other external collaborative programmes such as the FOM programme with KVI. Here there is only space to briefly summarize our findings in this area.

This group is leading the proposal for a European Fiber Network stretching from Amsterdam to Italy. There is at least a two-fold benefit here: this could help relate clock experiments in different locations for sensitive tests of fundamental constants; and at the same time it will prove a reference standard for Europe. A 260 km link with KVI has already been established. Additional activities in Applied Science include the ESA funded "Wind" mission measuring atmospheric scattering; a programme to study interstellar chemistry (carbon change); and the assistance in commercial development of fibre comb lasers, with Menlo Systems and IMRA.

Other applications of soft x-ray technology related to this are water window imaging and lenseless holography. The highly developed activity in generating ultraviolet radiation is currently leading to a new nationally funded programme in laser-based microscopy for imaging in the life sciences.

These are high value applications, and the group seems poised to make an important contribution here. One of our few concerns is that the group has not previously been culturally attuned to the filing of patents, but these new applied innovations really start to need intellectual property protection. We urge the group to begin patenting its technical innovations.

Viability

There are no concerns with the viability of this group. Following its restructuring referred to above, they have established a senior staff with youth, vitality, and common purpose. There is a good distribution of ages, and clear paths to succession, which will hopefully not even be necessary for the next decade.

Programme VU 2:	**Complex systems**	
Programme directors:	Prof. J.F. de Boer, Prof. F.C. MacKintosh, Dr. ir. E.J.G. Peterman, Prof. G.J.L. Wuite	
Research staff 2009:	15.61 fte	
Assessments:	Quality:	5
	Productivity:	4.5
	Relevance:	5
	Viability:	4.5

This programme aims to understand and develop quantitative techniques for measurement of complex biological systems, ranging from the single molecule level of cellular constituents to the imaging of whole tissues, using a combination of mostly optical/laser techniques and theoretical modelling. They combine a programme to understand fundamental physics principles governing biological systems, with programmes to help to solve frontier clinical problems using the techniques of the modern physics laboratory such as single particle manipulation.

The programme is subdivided into three groups, which interact strongly with each other:

- Single Molecule to Cell Biophysics focuses on structure-function relationships at the level of single molecules to whole cells.
- Theoretical biophysics and soft matter is currently focused primarily on the theory of the structure and mechanics of the cytoskeleton and similar related structures.
- Biomedical physics is the newest group and is concerned with developing novel optical methods to measure and characterize tissue for the purpose of diagnosing disease.

Our evaluation considers these groups together.

Quality
The first subprogramme developed a special instrument in fluorescent microscopy that enabled them to measure elasticity in a single DNA molecule and detect highly non-linear behaviour. They focus on the quantitative distribution of motor proteins and on the effect of such multiple pull.

The second subprogramme represents an interesting combination of physics and biology, looking at the stability of networks, the mechanical skeleton of cells, the balance between dimensionality and connectivity, with the aid of specially developed mathematical models.

The third subprogramme is a new section. They use low-noise optical coherence tomography (OCT) and split light over several wave-lengths. Building on previous work in Boston, they have contributed to the development of an endoscope with a spinning motor at the tip (see VU 3).

The groups are well aware of their outstanding international position and they generally have good complementary collaboration with similar groups around the world. A specific strength is the high level of collaboration between theoretical and experimental approaches that they have achieved. They manage to maintain an excellent balance between fundamental and applied research, and they do not experience these approaches as contradictory.

Productivity
The metrics concerning productivity are extremely high in this group. The mean citation score is 22.71 for Complex Systems. With 54 papers among the 10% most frequently cited papers, this

programme has the highest score of the VU programmes. In addition, 52% of their 184 papers are in high impact journals in biophysics.

The student production is similarly excellent with seventeen students in the years 2000-2005, only two of whom have left the program without finishing. A recent dip in the number of students is explained by the departure of a professor.

Relevance

The contributions of this group create a critical bridge between traditional areas of fundamental physics and all manner of applications in biophysics. This includes investigations of the core physics involved in DNA reactions with proteins, the use of single molecule methods to investigate the physical properties of viral capsids, the mechanism of DNA packaging and genome delivery, studies of non-equilibrium properties of cytoskeletal networks, their nonlinear elastic response, and the consequences of the simultaneous presence of both rigid microtubules and soft filament structures in cytoskeletons.

As the group turns toward biomedical and other clinical applications, the relevance will be more connected to the needs of the medical and clinical communities, rather than the traditional fundamental research communities. A significant consideration will be to choose areas where the science focus of this group is the driving force behind selection of topics, rather than trying to cover topics that are politically popular but not so much affected by science.

There are three license agreements, which generated 5M€ to date, and eight awarded patents.

Viability

The viability of the complex systems group is based largely on how it successfully combines theory and experiment in a collaborative research environment. This has led to a position of strong leadership in biophysics, not only in the Netherlands but also internationally, with many international collaborations. Plans to reinforce this include an increase in the theory effort and in medical imaging. Further strengthening theory has been identified as a high priority.

We also note a healthy distribution of strong mid-career reputation for the senior members of the group and early success of the younger members. The group has garnered two prestigious Vici awards during the period, and has had very good success in attracting funding at the group and personal levels.

Conclusion

We conclude that this is an extremely strong programme overall. It combines excellent science, high international visibility, relevance linking fundamental and clinical work, high productivity metrics, and an excellent record of graduate training. We believe that this group is well positioned to thrive even in an increasingly challenging funding climate in the Netherlands and in Europe.

Issues to consider for the future include:

- finding ways to retain credit for innovation at VU though patenting and licensing technology developed within the group;
- creating programmes that can allow students to easily cross the divide between fundamental science and biomedical applications;
- choosing problems where industry is the beneficiary but science is the lead motivation.

Programme VU 3: **Condensed Matter Physics**
Programme directors: Prof. Griessen (retired 2010), Dr. B. Dam, Dr. R. Wijngaarden, Dr. D. Iannuzzi.
Research staff 2009: 10.75 fte

Assessments:	Quality:	3.5*
	Productivity:	4
	Relevance:	4.5
	Viability:	no score (group will be dissolved)

*) A separate quality score of 4.5 is given for the activities of Dr. Iannuzzi

The research line on hydrogen storage has come to an end because of the retirement of Prof. Griessen and the departure of Dr. Dam. The group will be transformed into a Physics of Energy section, embedded in the other Energy initiatives of VU Physics. The work in the field of sustainable energy, with experiments to investigate water splitting by solar light on surfaces with natural or engineered electrical field configurations, will be strengthened further as soon as the vacancy for a professor in Physics of Energy will be filled in. The group has also worked on several fundamental topics (e.g., Casimir effect, self-organized criticality, search of chameleon fields, physics of avalanches). More recently, the subgroup of Dr. Iannuzzi has developed a proprietary "fibre-top" technology, with promising applications in biomedical sensing. This activity will be transferred to the new Biomedical Imaging group.

Quality
The numerous scientific contributions of the retired Prof. Griessen during the evaluation period have not been presented in the self-assessment report of the group. Dr. Wijngaardens work on superconductivity and self-organized criticality is quite diverse and has been published in a number of good to very good journal articles. However, due to the diversity of the research topics, the activities of this subgroup have not reached a critical level and overall cannot be considered leading nationally or internationally. The work of Dr. Iannuzzi has been similarly diverse in the past, even with some more exotic sidelines ("chameleon fields"). However, this subgroup is internationally leading in the development and exploitation of the promising "fibre top" technology, which has become the focus of the activities in the last five years and has earned Dr. Iannuzzi an ERC starting grant.

Productivity
The productivity within the programme has been excellent in the first part of the assessment period, but has decreased by a factor of two in the second half, despite of roughly constant fte-values and an even increasing total funding. In addition to 125 refereed articles, 9 patents have been filed or granted between 2004 and 2009.

Relevance
Apparently, the group has invested comparatively little effort in public outreach, but instead defines its relevance via patents and patent applications, some of which are close to commercialisation or represent the IP basis for a spin-off company. The latter ("Optics11") has been founded by Dr. Iannuzzi and has received a STW and a FOM Valorisation Grant. During the site visit, Dr. Iannuzzi presented to the panel several innovative product ideas based on the fibre-top technology, which indeed could become very relevant in biomedical sensing and imaging.

Viability

Here no score was given because the existing Condensed Matter Physics group will be dissolved and, thus, has no viability as such. However, convincing exit scenarios have been presented for both subgroups, which will merge into the future strategic themes "Physics of Energy" and "Physics of Life".

In response to the draft report, the VU Executive Board asked to add the following reaction:

The VU Department of Physics decided in spring 2011 to discontinue the activities in Condensed Matter Physics in favour of a new research group "Physics and Chemistry of Energy". The new research activity will have a strong interdisciplinary character. The new research group "Physics and Chemistry of Energy" will play a key role in the theme Science for Sustainability. We anticipate that the new research group will comprise two full professors and several positions at the level of assistant and associate professor, ensuring the long-term viability of this activity.

Programme VU 4: **Elementary Events in Biophysics**
Programme directors: Prof. R. van Grondelle, Prof. M.L. Groot, Dr. J.P. Dekker, Dr. J.T.M. Kennis, Dr. I.H.M. van Stokkum
Research staff 2009: 12.67 fte

Assessments:		
	Quality:	5
	Productivity:	5
	Relevance:	4.5
	Viability:	5

The programme aims at understanding the elementary events in biological reaction dynamics. This involves the study the transfer of excitations, electrons, protons in photosynthesis and enzymatics, the formation of a signalling state in photoreceptors, or how small molecular changes modulate the efficiency of photosynthesis (i.e. non-photochemical quenching). They use advanced spectroscopic tools and develop novel microscopic tools using nonlinear optical techniques to obtain images in deep-tissue with sub-cellular resolution.

The application of this line is in neurobiology and the study of larger scale phenomena in natural and artificial photosynthesis.

Quality
The group is one of the key players in the study of the early events in photosynthesis and has developed strong research lines in the fields of ultrafast biological reaction dynamics and biological photosensing, based on innovative laser experiments and state-of-the art data analysis.

The group is competitive on an international scale. The interests have migrated from photosynthesis to solar fuel, and this research will move to the Biophotonics group. The research group emphasizes five interrelated subjects:

(1) Primary Processes in Natural and Artificial Photosynthesis: Highlights include the discovery of the large-scale organization of the bacterial photosynthetic membrane; modelling the organization of the plant photosynthetic membrane; original studies of the oxygen-evolving reaction centre of Photosystem 2 charge separation; proof of a molecular mechanism for non-photochemical quenching, which is an important photoprotective regulation process in plants.

(2) Elementary Events in BioReaction Dynamics: This group has made the discovery that proton transfer can occur on a picosecond time scale, and that light-induced conformational changes in the enzyme POR determine catalytic activity. They have characterized the photocycle of photoactive yellow protein and of proteorhodopsin by multi-pulse spectroscopy. And they have found physical mechanisms that control the signalling state formation in photoactive yellow protein.

(3) Light-Driven Signalling: This group employs state-of-the-art transient absorption and emission spectroscopy and vibrational spectroscopic techniques, from ultrafast (fs) times to minutes. These experiments are conducted in the traditional, 'initiate-interrogate' way.

(4) Computational Biophysics
Time-resolved absorption and emission spectra are 2-dimensional data sets, the analysis of which in terms of physical models is mandatory. Software has been developed to perform the necessary manipulation of the data and is very successfully applied to a large number of experimental results.

(5) Biomedical photonics.
This program uses nonlinear optical techniques to obtain images in deep-tissue with sub-cellular resolution, with and without external contrast agents. Highlights include a deep tissue, label-free microscope for *in-vivo* applications, and demonstration of single-shot 2D OCT.

The group has developed a model for the dynamic reorganisation of the thylakoid membrane. A publication on brain slices in mice, which has relevance for Alzheimer research, has attracted much attention. A current focus is on determining the mechanism of optogenetic switches.

Productivity
Productivity in this group is high as measured by citations, papers, and the H-index, as well as productivity involving training throughput of students. The group has five tenured physicists, which is quite large. The number of PhD students is typically about 12 FTE, but in the past two years this has plunged to below 5 FTE

The group has attracted three Vidi award winners, who subsequently have been appointed as permanent staff members (Dr Kennis, Dr Groot and Dr. Frese, on tenure-track), and, recently, one Veni award winner (Dr Berera). The research programme is a major attractant for visitors within the framework of the EU-access.

Relevance
Group-trained postdoctoral fellows enter an academic career, or a career in government and industry. PhDs trained by this group find careers in science (postdocs), industry, medical institutions, government, education or sometimes elsewhere, but generally in knowledge-based jobs. VU-biophysics makes important contributions to the training of Master students in physics, laser sciences and medical natural sciences.

The group has made an important contribution to general understanding of the mechanisms of solar energy conversion and the important concepts of photosynthesis are applied in solar cell technology.

The work of this group is relevant to neurobiology and the study of macroscopic phenomena in photosynthesis. In addition, the insights about the primary events in biological reactions will elucidate the mechanisms and functions in enzymes. This could be of great importance in treating diseases.

Viability
The group is expanding; new staff is being hired, funds have been acquired. The expectations are that the group will grow to about 30 people. In that case, new facilities will be made available by the university, because the current building does not provide optimal space.

The succession of Van Grondelle in 5-6 years by talented staff in the current group is facilitated by his KNAW professorship.

VU is setting up novel laser-methodology to image fundamental processes in neurosciences, in close cooperation with the Technology Transfer office of the VU and the NCA.

Conclusion
The VU-Biophysics group combines high-level expertise in the study of ultrafast processes in biological systems. The study of the elementary events in photosynthesis is world-leading as

recognized by many prestigious awards to the members. The programme combines many innovative techniques, unique data-analysis and modelling theory. The staff has a combination of youth and experience. The laser-spectroscopic and biophysical expertise is now integrated into new microscopies, for neuroscience and membrane biophysics.

Programme VU 5:	**Particle and Astroparticle Physics**	
Programme directors:	Prof. J.F.J. van den Brand, Prof. P.J. Mulders, Dr. H.J. Bulten, Dr. T. Ketel, Dr. G. Raven	
Research staff 2009:	24.54 fte	
Assessments:	Quality:	4.5
	Productivity:	4.5
	Relevance:	4.5
	Viability:	5

The aim of this programme is the understanding of the fundamental particles and forces of nature. The Standard Model of particle physics is used as the basic toolbox to account for the structure of hadrons and matter at the subatomic level. To go beyond the Standard Model and find the underlying concepts and structure, laboratory experiments are carried out at the highest energies or precision, and cosmological observations are used.

The programme contains three sub-groups:

- *Phenomenology in and beyond Standard Model*: the incorporation of hadron structure effects in high energy scattering processes focussing on spin effects and spin-momentum correlations of quarks and gluons; studies of the phase structure of Quantum Chromodynamics (QCD) and studies on masses and mixing patterns of neutrinos using symmetries among the different families of quarks and leptons.

- *Gravitational physics:* experiments on the emission of gravitational waves (GW) by accelerated bodies, with advanced detectors LIGO, Virgo, GEO600 and LCGT.

- *B-physics:* precise measurements of the properties of the charged weak interaction in the decays of b-hadrons.

Quality
The scientific activities and achievements of this research programme are internationally very well recognised and favourably compare to the top-10% of comparable research efforts and results world-wide. The visibility and impact of this group in several international large-scale experiments and communities is well pronounced. Although these achievements are obtained within the (larger) groups of Nikhef, the Committee acknowledged that VU scientists play a leading role in planning, designing, building and running the various projects at Nikhef, and thus significantly and actively add to – and clearly also profit from – the excellent infrastructure and scientific reputation of Nikhef. VU scientists had and still have leading positions and convenorships in projects like LHCb and VIRGO. Especially the VU LHCb group plays a significant role in this multinational endeavour. The technological contributions of VU scientists to these projects are excellent; they are important and well recognised pillars for their collaborative success. The Committee rates the overall quality of this research programme to be clearly leading, for the projects pursued, on the national scale, and to be clearly recognised and – in some cases – leading on the international scale.

Productivity
This programme produced a rather large number of publications in well recognised, international journals. This is especially true for the experimental papers, which are – in most cases – signed by rather large experimental collaborations of many authors. While this situation is typical for most experimental particle physics programmes, VU scientists did and do have a significant direct

impact on many of these publications, through their overall contribution to projects like Babar, and in fact made leading contributions to many of these analyses, some of them with leading impact to the field world-wide. Likewise, the publication record of the theory group compares well to other strong theory groups on an international scale. The Committee realised, however, that conference reports - and thus, presentations of projects at international conferences – are not reported for the experimental groups. Similarly, review articles or publications aimed at the general public are rather rare. This led the Committee to slightly downgrade the rating of productivity of this programme from "leading on an international scale", which would be grade 5, to an actual grade of 4.5.

Relevance
The direct societal relevance of basic and knowledge-oriented research is normally very limited. In the case of this programme, significant technological advancements have been achieved in the field of developing particle detectors and related technological infrastructure. As typical in this field, however, such developments are not protected by patents, but are left open and available for all kinds of scientific and commercial uses. Education and technical as well as scientific training of large numbers of PhD students and post-docs, and the impact of this human capital on society and industry, makes the societal value of this field recognisable in many fields and aspects of life. The programme reports outreach activities and projects with industry, based on their technological developments for particle physics experiments. Altogether, the Committee regards the sum of these achievements, according to internally defined indicators, to be of very high international and leading national scale.

Viability
Future prospects of this programme are regarded to be of highest national and international standing, and are in fact excellent given the scientific importance, international standing and future relevance of these projects – LHCb as well as the gravitational wave projects. The programme is at the forefront of scientific research in both collider physics at the very highest energies, and in the physics of gravitational waves. The complementarity of these programmes ensures long-lasting viability in these fields, and offers very interesting future prospects also for students and young post-docs. The age structure of this group appeared to be very favourable and extends well into the future. The team gave a very motivated and dynamic impression to the Committee.

Conclusion
The overall impression of this programme is very good to excellent and of high international standing, comparing well to the top 10% of institutions in this field world-wide. The symbiosis with Nikhef and the concentration of basically two complementary programmes in particle and gravitational physics, together with the pronounced international networking, makes this programme a very attractive and fruitful part of basic research and student education in the Netherlands.

Appendix 1: Explanation of the SEP criteria and scores

The four main criteria for assessment are: Quality, Productivity, Relevance, and Vitality & feasibility. The assessment at the institute level primarily focuses on strategy and organisation, whereas the assessment at the level of the research group or programme primarily focuses on performance and activities of researchers and the results of their work (output and outcome).

Quality	The level or degree of excellence of the research, compared to accepted (international) standards in that field. The scope of the term 'research' is not limited to the research results. Research management, research policy, research facilities, PhD training and the societal relevance of research are considered integral parts of the quality of work in an institute and its programmes.
Productivity	The relationship between input and output, judged in relation to the mission and resources of the institute.
Relevance	Social, economic and cultural relevance. Aspects to be considered are: ▪ *Social quality*: efforts of the institute or group to interact in a productive way with stakeholders in society ▪ *Social impact*: how research affects specific stakeholders or procedures in society ▪ *Valorisation*: activities aimed at making research results available and suitable for application in product, processes and services. Committee members can also remark on relevance for the academic community, but the assessment should be on societal relevance.
Vitality & feasibility	The ability to react adequately to important changes in the environment. Also vision for the future.

The scores on a five-point scale are:

5 Excellent	Research is world leading. Researchers are working at the forefront of their field internationally and their research has an important and substantial impact in the field.
4 Very Good	Research is considered nationally leading. Research is internationally competitive and makes a significant contribution to the field.
3 Good	Research is considered internationally visible. Work is competitive at the national level and makes a valuable contribution in the international field.
2 Satisfactory	Research is nationally visible. Work adds to our understanding and is solid, but not exciting.
1 Unsatisfactory	Work is neither solid nor exciting, flawed in the scientific and/or technical approach, repetitions of other work, etc.

Appendix 2: Short profile of the members of the Committee

1. Subcommittee Groningen, Twente, Nijmegen (RUG, UT, RU)

Hilbert von Löhneysen, Physikalisches Institut, Universität Karlsruhe (TH). Physics of metallic layered systems and nanostructures, properties of strongly correlated electron systems (heavy-fermion systems, rare earth and transition-metal compounds), magnetism and superconductivity, metal-insulator-transitions.

Masao Doi, Department of Applied Physics, Graduate School of Engineering, The University of Tokyo. Research interests: Soft matter physics, rheology of polymers near the interface (adhesion, contact line motion), Modeling and simulation of polymeric materials.

Monika Ritsch-Marte, Full Professor for Medical Physics at the Medical Faculty of the University of Innsbruck (now Medical University of Innsbruck). Quantum Optics, especially laser fluctuations, squeezing, nonlinear optics, atom interferometry. Since 1998: Biomedical Applications of Lasers, especially optical micro-manipulation, (spiral) phase contrast microscopy, nonlinear microscopy (CARS microscopy), optoacoustics.

Albrecht Wagner, particle physicist, former Chairman of the Directorate of DESY in Hamburg. He was previously Professor of Experimental Physics and Research Director at Hamburg University. He has conducted scientific research at the University of Heidelberg and at the Lawrence Berkeley Laboratory (USA). From 1974 to 1986, he worked on experiments at DESY's DORIS and PETRA storage rings, and from 1982 to 1991 at the research center CERN in Geneva. In 1991, he took up a post as a professor of experimental physics at the University of Hamburg and became research director of DESY.

Friso van der Veen, Full Professor of Experimental Physics at the ETH Zurich since May 2000. Head of the Research Department of Synchrotron Radiation and Nanotechnology at the Paul Scherrer Institut in Villigen. 1990 - 1996: Technical director of the FOM-Institute for Atomic and Molecular Physics, Amsterdam.
1987 – 1992: Professor of surface physics, Leiden University.
1992 – 1997: Professor of technical physics, University of Amsterdam.
1997 - 2000: Professor of experimental physics, University of Amsterdam; director of Van der Waals-Zeeman Institute.

2. Subcommittee Eindhoven, Amsterdam (TUE, UvA, VU)

Friedrich Wagner, 1993-2008 Director Max-Planck-Institute of Plasma Physics. Retired 2008. Research interests: High-temperature physics and fusion research. Since 1999 Friedrich Wagner has been Professor of Physics at Ernst Moritz Arndt University in Greifswald, and since 2007 President of the European Physical Society.

Siegfried Bethke, Professor of Physics, Director Max Planck Institut für Physik. Research interests: Experimental Particle Physics at high-energy colliders, Development of particle detectors, Experimental tests of quantum chromodynamics, Experimental astro-particle physics.

Paul Chaikin, New York University. Soft condensed matter physics. Research interests: Effects of dimensionality, Coulomb correlation, disorder in condensed matter systems, spindensity-wave

states and superconductivity in organic metals, superconducting wire networks, colloidal physics, sedimentation in fluidized beds.

Phil Bucksbaum, professor of applied physics, director of the Ultrafast Science Center, SLAC, Stanford University. Main research interests:

- fundamental light-matter interactions, and especially the control of quantum systems using ultrafast laser fields.
- developing new sources of ultrafast laser light in the infrared, visible, ultraviolet, and x-ray regions of the light spectrum.

Jean-Louis Martin, director of the Laboratoire d'optique et biosciences, École polytechnique (CNRS, INSERM). Président of the sciebtific council of INSERM. Director of the SupOptique (Institut d'optique théorique et appliquée).

Martin Stutzmann, TU München, Walter Schottky Institute, Centre for Nanotechnology and Nanomaterials. Research interests: Defects and electronic transport in semiconductors, optical and spin resonance spectroscopy, hydrogen in semiconductors, Laser crystallization and processing of semiconductors, large area electronics and photovoltaics, silicon based sheet polymers, electronic properties of semiconductors with wide bandgap (III-nitrides, diamond, suboxides), CVD and MBE growth, high electron mobility transistors, semiconductor sensor devices and biosensors, biofunctionalization of semiconductor surfaces.

3. Subcommittee Utrecht, Delft, Leiden (UU, TUD, LEI)

Sanjoy Banerjee, professor of chemical engineering and director of the Energy Institute, City University of New York (CUNY). Research interests: the behaviour of systems far from equilibrium, including rapid phase transitions, turbulence and nonlinear phenomena such as dendrite formation in electrochemical energy storage systems.

John Brady, Chevron Professor of Chemical Engineering, California Institute of Technology. Fluid mechanics and transport processes; Complex and multiphase fluids.

Jonathan Richard Ellis, Clerk Maxwell Professor of Theoretical Physics at King's College London. After post-doc positions at SLAC and Caltech, he went to CERN and has held an indefinite contract there since 1978. His activities at CERN are wide-ranging. He was twice Deputy Division Leader for the theory division, and served as Division Leader for 1988–1994. He was a founding member of the LEPC and of the LHCC.

Rob Hartman, Director Strategic Technology Programme ASML. Member of the Committee Action Plan Physics 2007 and member of the mid-term review committee for Physics research at the technical universities in 2008. ASML is a world leader in the manufacture of advanced technology systems for the semiconductor industry. The company offers an integrated portfolio for manufacturing complex integrated circuits.

Jürgen Kurths, Head of research domain Transdisciplinary Concepts & Methods at the Potsdam Institute for Climate Impact Research (PIK), where he examines the dynamics of complex networks and brings a new approach to the understanding of climate change and its interaction with ecology and socio-economy. He is also professor of Nonlinear Dynamics at the Institute of Physics at the Humboldt University of Berlin.

Gerhard Rempe, Director and Scientific Member at the Max-Planck-Institut of Quantum Optics and Professor at the Technical University of Munich (since 1999). Research interests: Bose-Einstein condensation, Cavity QED in an optical resonator, Cold Polar Molecules, Quantum Information Processing.

Erio Tosatti, International School For Advanced Studies (SISSA),Trieste. Research interests: Nanofriction: Theory and Simulation, Theory of Metallic Nanocontacts, Especially Magnetic, Mott Insulating and Unconventional Superconducting States of Fullerides, Strong Electron Correlations at Surfaces, Physics of Ultra-High Pressures, Quantum Effects near Ferroelectric and Structural Phase Transitions.