REPORT PANEL 3: PHYSICS AND THEORETICAL PHYSICS

GENERAL ASSESSMENT OF THE RESEARCH FIELD

The review panel spent approximately three days listening to presentations, and interviewing professors, other staff and students in the two Units of Assessment. We also visited laboratories and workshops. The staff and students had clearly taken the review very seriously and had invested much time in it. They were also very helpful and responsive, which made our task quite pleasant.

While this review covers research and not teaching, in some (but not all!) cases the attitude seems to be that teaching is a burden to be minimized by as much research funding as possible. This attitude was surely not held by Richard Feynman! Good, enthusiastic teaching will attract great students, and they in turn will stimulate researchers. The School of Physics has too few courses at undergraduate level; finances should not prevent all professors from teaching at all levels, independent of their research expertise.

We noted that most senior staff have spent most of their careers at KTH, with perhaps a few post-doctoral years abroad. This is not healthy; one would ideally see less internal promotion and more external recruitment of 30-50 year-olds. This will only happen if the research programme is world class, which is achievable (and it is in some areas). We are aware that external recruitment bears the danger of further fragmentation, in particular when connected with a change of research direction, but we believe this can be controlled.

As the “T” in KTH is Technology, it is important that the groups innovating instrumentation are very mindful of commercial applications, patents and use of the Technology Transfer Office. We were not able to judge whether this Office is adequate at KTH, but clearly patenting inventions should be made as simple as possible.

The two units assessed have many young, dynamic and visible professors, but they are too dependent on outside grants, making it difficult to bridge finances between projects and which are often inadequate to hire the best PhD students or post-docs. More KTH funding for research should be made available. We also recommend creating a special highly competitive PhD “Excellent Student” Fellowship to attract first class young people.

At present materials-related research in a broad sense is spread over different departments at KTH and SU. The idea of creating a Centre for Functional Materials (or simply, Centre for Materials Science), with groups in both physics and chemistry at KTH and SU, at Kista and AlbaNova, is a strong one. The idea has been around for some time and should be made real. This would make it possible to create a strong interdisciplinary research and PhD programme, attract post-docs and improve on the external funding, as one would be able to compete within large national and European research initiatives.

UoA Experimental Physics

General Assessment

The research covered by this unit spans distance scales from the very smallest (elementary particles) to the very largest (astrophysics), with nuclear, atomic, molecular, materials and biological processes in between. This diversity is both a strength and a weakness. It gives a richness to the programme and, in a few cases, a cross fertilization; for example, detectors for particle physics, astrophysics and medical imaging sometimes use common techniques. On the other hand, in a unit of this size, it results in many small groups (sometimes as small as a single person) with little in common (fragmentation) and a range of effectiveness. This is not to say that there is a correlation between size and effectiveness; we found the smallest group (atomic and molecular physics) to be very effective. Naturally, most groups want more money and (so) more people, but the emphasis should be on reaching, or in some cases maintaining, the highest quality by building groups of at least several permanent staff members.

Overall, we found that a main strength of the unit is its internationalism, which gives experimental physics at KTH a visibility worldwide. Moreover, it provides KTH physicists with access to the best physicists (and their ideas and equipment) in the world, and their PhD students, access to post-doctoral positions abroad. In experimental particle physics, nuclear physics and astrophysics, international collaboration is indeed mandatory; there are practically no projects small enough to be purely national. Even in other areas where experiments are small enough not to *require* large international collaborations, they are sought, as we are pleased to note.

Performance against Evaluation criteria

Scientific Quality
The majority of the UoA currently performs at an internationally high standard.

Applied Research Quality
The majority of the UoA currently performs at an internationally high standard.

Scholarship
Excellent in some parts/individuals of the UoA.

Vitality and Potential
Excellent in some parts of the UoA, good in the remainder.

Strategy
Excellent but challenging to achieve.

Experimental Particle Physics
Four Swedish experimental groups (KTH, SU, Lund and Uppsala) formed a single group ("consortium") to participate in the D0 experiment at Fermilab (USA), an activity which is now winding down (for KTH) with only a minor analysis activity. Nevertheless, the Tevatron is breaking luminosity records monthly, with the highest energy collisions pre-LHC, the detectors are in excellent shape and there is still much important physics coming out. Their withdrawal is somewhat premature, but they decided to concentrate on the LHC, specifically the ATLAS experiment, for which they helped build some detectors. However for ATLAS, the "Swedish consortium" appears to have reverted to four separate groups, with some interactions but not fully coherent. As a result, the KTH group risks becoming invisible, with some four to five people (including students) among a world-wide collaboration of over 2,100 scientists. They could probably become prominent only by doing an outstanding original analysis. While this will hopefully happen, we did not see evidence of such a "wresting secrets from Nature" mind-set. They say they want to look for super-symmetric particles; so do probably more than 500 other ATLAS physicists. A topic more off-the-beaten-track would perhaps be riskier but well worth considering. Internal politics aside, reforming a coherent

“Swedish consortium” would greatly strengthen the group’s chances of success and visibility, and we recommend that they move in that direction.

Studies of radiation doses in the International Space Station (by Astronaut Fuglesang) are a valuable contribution, although it used mainly pre-existing code.

We include here remarks on the unit’s technical contributions, which are not particle physics but use techniques developed in that field. These are interesting applications, simulating visual systems and seismic signal analysis with pulsed coupled neural networks (PCNN) … “a meteorite hit was located this way” … and an “electronic nose” which can detect and identify explosives and could have medical applications. When asked about patents and industrial collaboration (and funding), a senior member of the unit stated that he was not very motivated to pursue that. He should be.

Astroparticle Physics
In astroparticle physics, two young dynamic professors animate a lively and active group of one researcher, two post-docs and seven PhD students. The two have complementary profiles, Mark Pierce being a particle experimentalist and Felix Ryde an astrophysicist. Both are involved in prominent international research programmes. Their activities are funded by the Swedish Space Agency, the High Energy Astrophysics and Cosmology Centre (HEAC), and a Linné grant for the Cosmoparticle Collaboration. Mark Pearce’s team has contributed to important detector parts on the PAMELA satellite, which has been operational since 2006. They now concentrate on measuring the antiparticle content of local cosmic rays. Felix Ryde is a gamma-ray burst specialist. His interpretation work on relativistic jet physics is much appreciated abroad. He is part of the GLAST satellite collaboration. This new gamma-ray telescope has just started its operations. Felix Ryde will provide strong modelling support to the gamma-ray burst observations that will continue for five to ten years with GLAST.

One could worry that the two science topics pursued in such a small group are disconnected. The two professors have already taken action to remedy this problem and to join their instrumental and theoretical expertise and efforts in a common project, PogoLite. This balloon-borne gamma-ray polarimeter, to be flown from northern Sweden in 2010, will provide key constraints on the radiation and magnetic field structure in relativistic plasma jets from astrophysical sources. The KTH professors have taken visible roles in this international project. Studying relativistic jets is clearly a major scientific goal in high energy astrophysics. We strongly recommend that they keep concentrating on this prominent topic that makes excellent use of their GLAST and PogoLite investments, and which reinforces their current link with the Stockholm University groups at AlbaNova. International consortia have recently been formed to promote and prepare the next generation of x-ray and gamma-ray telescopes that will provide key data on relativistic jet physics after 2015. We recommend that the KTH professors initiate contacts with these programmes in the near future.

The group is presently too small to make a strong impact within the large multi-country collaborations that prepare future instruments. We strongly recommend that KTH adds a young professor or associate professor with observational expertise on jets and compact objects to strengthen the emerging synergy in the group and improve the group’s visibility abroad beyond their personal successes.

High-energy astrophysics and cosmic-ray physics have few direct applications to industry, but, from the teaching point of view of a prominent engineering university, there is considerable added value in training Master's and PhD students within international collaborations and on space programmes where they can learn about the rigorous management structure, quality assurance and testing plans that ensure the instrument reliability and technical communications across many teams and countries. This management structure also applies to other fields like particle and nuclear physics instrumentation. The Physics Department may want to consider adding related lectures at the graduate student level. It has proved useful in France both for students who stay in research and for those who go to industry. The Panel gives high marks for the "scholarship" aspects of this group.

Atomic and Molecular Physics
The main focus of this small research group, with Prof. Elisabeth Rachlew being the only KTH staff scientist (and the only woman physics professor at KTH), is the development and application of spectroscopic tools for the diagnostics of hot fusion plasmas. The successful experimental programme, which allows for contact-free investigations of the plasma behaviour under the influence of electric and magnetic fields, radiation, impurities, retaining walls, etc., is performed within international collaborations mainly at JET and MAST in the UK and at the German ASDEX-U experiment and is part of the European fusion programme of EURATOM. These investigations are complemented by more basic studies of atomic and molecular systems with synchrotron radiation at MAX in Lund and ELETTRA at Trieste, relevant for modelling radiative processes in plasmas. The programme is well funded mainly by EURATOM and the Swedish Research Council, the results are published in more than 50 papers, and six PhD students (two females) graduated in the assessment period, giving vivid evidence of Prof. Rachlew's vitality as a teacher and her devotion to research. The Panel also appreciates her ongoing involvement in outreach.

In view of her upcoming retirement and the lack of junior staff, Prof. Rachlew is planning to concentrate her future research within her international collaborations on the development of new spectroscopic techniques for upcoming fusion experiments such as ITER. In view of the limited personnel resources, the Panel recommends discontinuing this line of research in the KTH Physics Department with the retirement of Prof. Rachlew, and to leave the subject to e.g. the Alfven Institute.

Nuclear Physics
The research of the KTH nuclear physics group is concentrated on experimental and theoretical studies of the structure of nuclei far from stability, and on applications of radiation detectors in medicine and industry. The experimental activities take advantage of the recent, worldwide development of rare isotope facilities and is focused on γ-spectroscopic investigations of nuclei at extreme proton/neutron (Z:N) ratios, deformations and angular momenta using modern high-resolution germanium detector arrays constructed in international collaborations. A recent highlight of their research is the first evidence for a new form of collectivity in very neutron-poor heavy nuclei, induced by p-n correlations becoming relevant when approaching the symmetry line $Z = N$. This result is an excellent example of one of the strengths of the KTH group, which has a strong and well integrated theory branch working on basic nuclear structure problems as well as on issues closely connected with the experimental nuclear research at KTH and many other experimental groups worldwide. In this example, their first realistic calculations of the specific pairing effect were decisive prerequisites for the interpretation of the data. Moreover the KTH nuclear physics group is playing a leading role in the development of the γ-ray tracking method, based on segmented germanium detectors and digital signal processing. The method allows reconstruction of a γ-ray interaction position, which is indispensable when one wants to perform high resolution γ-

ray spectroscopic experiments. Using their technological knowledge of modern radiation detectors, the group is also successfully developing new detectors for applications, such as γ-ray Compton imaging and polarimetry based on planar, segmented germanium detectors, and optical sensors based on silicon photomultiplier technology (patent pending). The results of the group obtained during the assessment period are well documented in more than 100 peer-reviewed publications, and seven PhD students, five of them female, graduated from the group.

The KTH nuclear physics group is very well embedded in both the Swedish and the European nuclear physics community, and their expertise in theoretical nuclear structure physics, nuclear γ-ray spectroscopy, and the development of position sensitive germanium arrays has resulted in a high international visibility. This is also reflected by the leaders of the group being spokespersons for a several international collaborations, performing experiments at European facilities such as Jyvaskyla, GANIL, GSI, dealing with the use and development of modern γ-detector arrays. To finance their research, the group successfully applied for external grants from several Swedish and European sources.

The KTH group, together with the other Swedish nuclear physics groups, views the future international radioactive beam facility FAIR at GSI as their prime research centre for the coming two decades. Consequently, the group is strongly involved in the development of the tools required to use effectively the exotic beams for nuclear structure studies at the borderline of stability. They are an integral part of the AGATA project and several other experiments being prepared for FAIR. At SPIRAL2 at GANIL, a future enlargement of the GANIL radioactive beam facility, the group is planning to participate in an upgrade of the EXOGAM array using the tracking technology presently being developed for the AGATA project. These involvements will enable the group to perform an exciting, future-orientated research programme at two upcoming, world leading exotic beam facilities. In addition, the group is planning to continue its spin-off studies on radiation detectors, which exhibit great potential for medical and industrial applications. The Panel views the research strategy of the nuclear structure group to be well focused, future orientated and to have an excellent potential for being highly successful. It is well adjusted to the potential of the group provided its present personnel strength can at least be maintained and an adequate funding level can be secured.

UoA Theoretical Physics

General Assessment

The Theoretical Physics Department also covers diverse areas, from particle physics to condensed matter, materials and biological physics. Theoretical nuclear physics, being part of the experimental nuclear physics group, has been discussed in the previous Unit, where we have noted the excellent synergy between experiment and theory. This is much less evident in particle physics, and the experimental astroparticle physics group does not have the potential benefit of a direct counterpart in theory. We recommend below that the theoretical particle physics group could, and should, strengthen such ties.

The theory groups are small and too often lack adequate funding, with the risk of becoming under-critical. All groups would like to see more funding for PhD students with the possibility to react fast if an excellent student appears. One way to deal with these issues may be to pool funding from the different groups, as well as to submit joint proposals between the groups to fund graduate students. Nevertheless we note a healthy throughput of PhDs, nine graduating since 2005, with 10 students at present.

Performance against Evaluation criteria

Scientific Quality (Basic)
Part of the UoA currently performs at a world-leading standard with the main part performing at an internationally high standard.

Applied Research Quality
Part of the UoA currently performs at an internationally high standard with the main part performing at a nationally high and internationally recognised standard.

Scholarship
Emerging across the majority of the UoA.

Vitality and Potential
Good across the majority of the UoA.

Strategy
Excellent but challenging to achieve.

Theoretical Particle Physics
The Particle Theory group has a young and dynamic leader with plenty of ideas, leading to a wide range of topics, perhaps too wide for the group size. Some topics relate to LHC physics (hyperbolic extra dimensions, "unparticles") but we did not see evidence of close interactions with the experimental LHC group; together they might develop a realistic plan for an off-the-beaten-track analysis that is not too risky, but may be guaranteed to make useful measurements if not a "discovery". Another area is calculations of dark matter annihilation (to neutrinos or to photons), which seem to be much too rare (and with too much background) to be detectable; as soon as the group is convinced of this they should move on to phenomena which are more likely to be accessible to experiment. They should also strengthen links with the Astroparticle Physics group. We appreciate their many international collaborators, and their outreach efforts. Prof. Ohlsson has a high international reputation in particular for his topical work on neutrinos; we hope he is able to build on this without compromising LHC-related studies.

Theoretical Condensed Matter Physics
This group is relatively small with a senior staff of one professor, one assoc. professor, and 1.5 researchers (the other 50% in collaboration with Materials Science at KTH). There are presently two graduate students, one of whom is part time. The group is quite productive and publishes in leading international physics journals. Recent highlights are found in Phys. Rev Lett. and Science, i.e. the scientific output is at a high international level. The group addresses basic problems of current interest in condensed matter theory and materials science such as heavy fermion systems, magnetism, high-temperature superconductors, optical lattices, the Ising model for two- and three-dimensional grids, high pressures and melting. Recent cross-disciplinary molecular dynamics simulations of the rigidity and the structural properties of the Earth's inner core deserve special mention (in collaboration with the Materials Science group at KTH). Similar simulation techniques have potential applications to engineering physics and chemistry, such as diffusion and corrosion problems and degradation of materials related to nuclear waste storage. However, the Panel feels that the list of different topics is a bit too

wide for a group as small as this, and that one might gain from focusing or joining forces with other groups or institutes.

Because of the smallness of the group it is hard to achieve a strong public outreach activity. External funding is received from the Swedish Research Council-VR. The present level is inadequate, however, as most of the VR funding covers salaries for the senior staff, which leaves too little for PhD students and post-docs. There are no EU grants received. However, there is potential for improving on the present situation. As NORDITA is relocated to Stockholm at the AlbaNova site strong daily interactions should become possible, provided NORDITA makes condensed matter theory one of its priority areas. KTH should help to make this come about. The idea of creating a Centre for Functional Materials (or better, Centre for Materials Science), either virtual or physical, with groups in both physics and related chemistry at KTH and SU at Kista and AlbaNova is a strong one and should be pursued. This would make it possible to create a strong interdisciplinary research and PhD programme, attract post-docs and probably improve on the external funding, as one would be able to compete with large national and European research initiatives.

Theoretical Biological Physics
This group has published some significant and highly cited research, including large-scale molecular dynamics simulations of bio-membranes. These types of calculations are considered by many in the field to be as valuable as experimental results, so there is considerable interest in further developing these capabilities with pharmaceutical companies, and probably with Swedish funding agencies. The size of the group, consisting of one Professor with only two graduate students, is really small, particularly when compared to other groups in the field. Judging by the number of publications per year, the output of the group is moderate, but the publications are highly cited, showing that they have a solid impact on the field. Nevertheless, the funding of the group is weak. This is surprising given that there must be industrial as well as governmental support for this type of work. It appeared that the group has little interest in seeking new funding opportunities.

We see a real chance for more interaction between this group and that in *Statistical Physics,* and recommend that they explore these possibilities. The former group's research on soft matter would also fit into the "Centre for Materials Science" mentioned above.

Statistical Physics
The research activities of this group cover a wide range of topics of current interest, and they get high grades for this leading edge research. Given the similarities of some of the research areas with the *Condensed Matter* group, we strongly urge these groups to work more closely together and to promote the "Centre for Materials Science". Such a Centre, along with the move of NORDITA to Stockholm, would be a great opportunity for KTH to achieve world class research in Materials Physics, with a theory core made up from the *Condensed Matter* and *Statistical Physics* groups.

The group is small, with one professor, one associate professor and one assistant professor, plus a graduate student. They have a good record of publications in Phys. Rev. Lett., Nature Physics, and other top journals. The members enjoy good international reputations, and very strong collaborations add to the high visibility of the group. Despite the positive and energetic aspects of this group we do have some concerns. Emphasis was placed by the unit on current topics such as supersolid He and graphene, quite fashionable, but where they do not yet have publications. The group's activities are quite wide-ranging; more focus on the most important topics is desirable. There are also examples of outstanding collaborators, despite relatively few (albeit strong) publications. Some promotion paths within the group have been very rapid (e.g. PhD 1999, Assistant Professor 2003, Associate Professor 2008). While it may be justified in specific cases, the Panel recommends that the administration reassess the "promotion culture" at KTH.

Mathematical Physics

The quantum field theory group has a strong record of publications and a good sense of the important research areas to which his small group can contribute. The group interacts with other members of the Condensed Matter and Statistical Physics groups, but it seems to us that the collaboration with these groups at the Physics Department at AlbaNova, as well as with other relevant research groups in materials science at KTH, could be intensified; there are many areas of common interest but not much in the way of explicit collaborations. One would like to see more joint publications and joint student projects with these other groups. There were other research directions such as anomalies and current algebra where we had less sense of the relevance of the work to other KTH research. There were some highly cited papers, but mostly from the 1980s, and the connections of the recent work of these areas with condensed matter, statistical physics or experiment were not clear to us.