Vrije Universiteit Brussel

High-Energy Physics

A proposal for a VUB research center

Department of Physics

November 28 2011

1 Introduction

The study of fundamental interactions between the building blocks of Nature at high energies and of the composition and structure of our Universe requires a strong interplay between experimental and theoretical research of physics processes at both the smallest and largest scales. During the last decades the community made enormous progress towards a thorough understanding of Nature in fields like collider physics, astro-particle physics, cosmology and string theory as well as in the development of novel methods and techniques needed for this. This is one of the core disciplines within physics as can be seen from the fact that high-energy physics and closely related fields received 28 of the 67 Nobel Prizes in Physics since 1945.

In our quest towards a full understanding of Nature at its most intimate level, the *Standard Model of Elementary Particle Physics* (SM) was developed. The SM predicted numerous novel phenomena – most of which have been discovered by now – and withstood uncountable experimental tests with unprecedented precision. Despite its enormous success, the SM raises new questions as well, like the mechanism to provide the measured masses to the elementary particles and the related breaking of the electro-weak symmetry. In addition it fails to account for various aspects observed in the Universe, like the origin and nature of the illustrious dark matter and dark energy, as well as the understanding of the fundamental parameters governing the structure of our Universe. These phemomena reflect some of the most notable examples which are essential targets for our current research activities during the next decade.

Various research centers are being defined around the world with the intention to have a major and leading impact during these exciting times. Both Brussels universities, VUB and ULB, host excellent teams covering a broad spectrum of relevant expertise in the interdisciplinary field outlined above. With a total of about 90 scientists in high-energy physics scattered in different teams on one single campus, we have the potential to evolve towards a Brussels center of excellence which can compete at the frontline of international scientific research. It is our intention to exploit the complementarity of the present research and reinforce the mutual collaborations and interactions such that the research on high-energy physics in Brussels evolves into a leading institution in the field of high-energy physics.

The variety of the various research activities at the VUB collected in the experimental and theoretical (astro)particle physics groups should be complemented with a bridge between the different domains, namely high-energy physics phenomenology. Recently this activity was successfully initiated at the VUB, funded via a Concerted Research Action[1]. The creation of a phenomenology team not only added new high-energy physics activities at the VUB, but also re-enforced the potential of the present experimental and theoretical teams in a unique way.

The current proposal is a natural consequence of this Concerted Research Action, which

[1]The Concerted Research Action *Supersymmetric Models and their Signatures at the Large Hadron Collider* was introduced by Profs. B. Craps, C. De Clercq, J. D'Hondt and A. Sevrin with B. Craps and J. D'Hondt as PI's. More details on `http://we.vub.ac.be/dntk/GOA.html` .

started a bit more than a year ago. The plan is first to carry out in full the Concerted Research Action project as planned, and then to extend it to a broader program. The proposal aims to embed the VUB groups active in (astro)particle physics, including the recently created phenomenology team, into a strong high-energy research center with about 50 members. The requested funds will allow us to bring the various teams closer together and strengthen the activities within a coherent structure, which will result in a very attractive center for high-energy physics at the international level. The funds obtained through this proposal will be dominantly used to attract top-level post-doctoral researchers and PhD students keeping a strong emphasis on research that connects the various groups.

2 People

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3 Strategic Plan

Team structure The proposed Research Center will involve all VUB groups active in the field of high-energy physics: two experimental groups (Collider Physics (Work Package 1) and Astro-Particle Physics (Work Package 2) known as the VUB research team ELEM) and one theory group (Theoretical High-Energy Physics (Work Package 3) known as the VUB research team TENA) together with the recently started phenomenology group providing the bridges between the groups. Its current composition is schematically given in table 1.

Group	Collider physics WP1	Astro-particle physics WP2	Theory WP3	Phenomenology
Faculty	4	2	2	0
Postdocs	3	4	5	2
PhD Students	6	3	4	2
Technicians	3	0	0	0
Secretaries	2			

Table 1: The composition of the teams involved in the present proposal. The members of the phenomenology subgroup are jointly embedded in the theory and the collider physics groups.

Overall purpose and scientific questions The main purpose of this proposal is the consolidation of the groups involved and in particular a further strengthening of the links between the groups. This will broaden our scientific reach to address the contemporary questions in the field of high-energy physics. Our currently running Concerted Research Action establishes a very concrete link between WP1 and WP3 by the creation of a team focusing on phenomenology, the link between theory and experiment. This team, shared between the experimental and theory groups, is now in place (and growing fast) and is currently mainly focusing on specific models of supersymmetry breaking (gauge mediation) and their signatures at the Large Hadron Collider. It sets up a complete chain from cutting-edge theoretical models all the way to detector signals. In addition to strengthening the three teams, the proposed Research Centre will continue the efforts started with the Concerted Research Action grant and broaden them to include astro-particle physics research.

From the scientific point of view the groups involved in this proposal focus on high-energy physics and aim at unraveling the laws of nature at the most fundamental level. This includes studying matter at very small scales – or equivalently at very high energies – using the CMS detector at the Large Hadron Collider. For energy scales beyond the reach of the LHC we make use of the most energetic particles coming from the cosmos, as they are detected by the IceCube observatory. This allows us to address questions related to the fundamental physics processes involved in the most energetic phenomena in the Universe, the nature of dark matter and the structure of primordial quark-gluon plasma which involve understanding physics at both the largest and the smallest scales at the same time.

WP1: Collider Physics The LHC was designed to explore physics at the TeV energy scale where novel physical phenomena are expected to appear. The exploration of the mechanism of electroweak symmetry breaking (e.g. one or more scalar particles), the search for supersymmetry and possible new physics phenomena and the understanding of the family structure of quarks and leptons are among its main tasks. After decades of preparation the LHC started its research program in 2010 at 50% of the design energy. Increases in the luminosity have already allowed exciting measurements like the first observation of top-quarks at CERN, something the VUB was closely involved in, just like the consecutive publications in the field of top-quark physics. After a luminosity ramp up in 2011-2012 there will be a one-year shut-down of the LHC to prepare the machine for operation at design energy and nominal luminosity, expected to be achieved in 2016. During the shut-down, the CMS experiment will be upgraded, but most importantly the very large dataset that has been collected in 2010-2012 will be scrutinized for subtle signals of new physics.

WP2: Astro-Particle Physics The research of the astro-particle physics group is centered around IceCube, the world's largest neutrino observatory at the South Pole. With the detector completed in December 2010, the data acquisition is now in full progress covering an energy range of 500 GeV to 1 PeV. The detector opens a whole new window on the universe: astrophysical and cosmological observations are now possible using neutrinos, revealing parts of the Universe not accessible by other messengers. As such, this research field is poised to yield unexpected discoveries. Apart from a search for high-energy neutrinos from point sources and transient events, which would provide insight in the sources of the most energetic cosmic rays, detection of cosmic ν_τ would allow to study neutrino properties. IceCube's DeepCore component lowers the energy threshold to about 10 GeV. Concerning the search for indirect cosmic Dark Matter signals this yields an increased sensitivity for lower particle masses and as such provides a complementary means w.r.t. the LHC experiments to search for new physics phenomena. Furthermore, in case new particles (e.g. SUSY) are discovered at the LHC, IceCube could provide the confirmation that indeed these new particles are related to Dark Matter. Using the surrounding IceCube sensors as an active veto, the DeepCore signals will enable a study of sources in the Southern hemisphere. This allows investigation of Galactic objects, including the Galactic Center and the black hole within it, with this unique neutrino observatory.

WP3: Theoretical High-Energy Physics The role of theorists is to build models that can eventually be tested experimentally. Roughly speaking, one distinguishes "deductive" and "inductive" methods. The deductive approach starts from elegant, symmetric, consistent models (e.g. string theory) and then tries to make contact with the (less symmetric) real world by deriving predictions from the models (and comparing them with experimental data). The inductive approach starts from experimental data and constructs (less ambitious) models directly aimed at explaining specific data, putting less emphasis on completeness or mathematical consistency. The VUB theory group has traditionally taken the deductive approach, and it still characterizes a lot of its research, such as the study of string

compactifications, string theory models of the big bang singularity, etc. While the eventual aim of this work is to make testable predictions, our level of understanding of string theory as a fundamental theory is such that direct tests should not be expected within the next few years. A recent development in our theoretical research is a shift towards models more directly aimed at comparison with experiments. One manifestation of this is an emphasis on models of supersymmetry breaking, which will within the next few years be compared to LHC data. Another line of research is the use of techniques originating in string theory (in particular the gauge/gravity duality) to try and explain specific features of the quark gluon plasma created in heavy-ion collisions, including its fast thermalization as well as observed fluctuations in the angular distribution of particles.

4 Annex to the Strategic Plan

For the first three years, we plan to complete the execution of the Concerted Research Action project *Supersymmetric Models and their Signatures at the Large Hadron Collider* as planned. This will certainly establish a strong and very concrete link between the WP1 and WP3 teams. In particular the research will coherently stretch from the development of theoretical models all the way to collider signatures at the LHC. The specific theoretical models on which our phenomenology will continue to focus (at least initially) are gauge-mediated supersymmetry breaking. As with any specific model directly relevant to LHC physics, the risk exists that all or most of their parameter space may be ruled out experimentally before the end of the project, in which case our focus would obviously shift to other models (strongly guided by the future results of LHC) in addition to activities in the field of astro-particle physics, as outlined hereafter. Nonetheless the techniques developed to derive experimental signatures from theoretical models will remain relevant regardless of the fate of any specific model.
From the fourth year onwards, the research center funding will be used more broadly towards the various research directions we are active in, but a strong emphasis will remain on links between the various subfields, in particular between experimental and theoretical research. In what follows, we provide some details on the various work packages and on the financial planning.

WP1: Collider Physics The coming years are expected to allow the LHC to probe rare physics processes, which we will attack in two ways: by detailed studies of the top quark sector and by direct searches for new physics phenomena. In the first category we established a strong and successful group at the VUB at the frontline of top quark physics within the CMS collaboration as well as in the search for fourth generation chiral quarks. The award of an Odysseus II grant in the CMS group allows us to extend the program to direct searches in the supersymmetric sector and other more exotic scenarios. These topics are well connected to the activities of the phenomenology group at the VUB. To maintain cohesion between the analysis teams the searches for new particles will be making use of very similar final states as top quark decays and will make use of the already existing expertise from top quark reconstruction, such as jet energy calibration, advanced quark mass reconstruction techniques and b-quark tagging. As the LHC is a discovery machine, but as we do not know what we will discover it is important to stay flexible. The diversity present in top quark physics analyses with guaranteed results and in general searches for supersymmetry allows us to rapidly shift our focus whenever surprises in the data appear.

WP2: Astro-Particle Physics This research comprises searches for high-energy neutrinos from cosmic point sources and transient events, detection of Dark Matter signals, detection of high-energy ν_τ and detection of ultra-high energy (GZK) neutrinos. The VUB astro-particle physics activities started in 2000 with the AMANDA experiment, the predecessor of IceCube. The group focused on studies of point sources and indirect dark matter

detection and later on participated in the construction of IceCube. In 2009 the VUB team received a major boost by the award of an Odysseus I grant with which the research activities were extended towards cosmic transient events (e.g. Gamma Ray Bursts). With the IceCube detector (including its DeepCore component) completed in December 2010, we participate in the detector commissioning, software development and reconstruction optimisations of the combined arrays to build up knowledge and competence to perform the foreseen analyses. This iterative process requires skills in the areas of data analysis, understanding the detector performance and software programming, all of which are covered by the various team members. In particular, our group has developed innovative statistical techniques to improve the sensitivity for neutrinos originating from transient cosmic phenomena. Our group is also involved in the design of elaborate trigger and veto algorithms to study (Galactic) sources in the Southern hemisphere, as indicated before, and in the development of a detector (ARA) for GZK neutrinos which provide the only means to study the ultra-high energy parent particles, since the latter are not able to reach the Earth. The strength or absence of their flux provides information about the composition of these mysterious cosmic ray particles.

WP3: Theoretical High-Energy Physics In addition to continuing their work on more formal aspects of string theory and quantum field theory, the theorists will further reinforce their investigations of well-motivated models whose predictions can be compared with experiments in the near future. One focus will be on theoretical models of (super-) symmetry breaking and their collider and cosmological signatures. Another focus will be on the use of string theory techniques to study real-world systems, in particular the quark-gluon plasma created at the LHC (as well as at Brookhaven), where fruitful interactions with the Collider Physics group can be anticipated.

Financial planning Each of the three groups involved will typically have 4-5 postdocs and 4-5 PhD students, most of whom will be funded by other sources. The Research Center will fund one postdoc at each group who will be carefully selected to ensure that he or she has the necessary skills to intensively interact with the other groups. In addition the research center will provide funding for 3 PhD students. During the first three years we intend to complete the Concerted Research Action project *Supersymmetric Models and their Signatures at the Large Hadron Collider* as planned. We were awarded a 5-year budget of 1.18 Meuro – so approximately €240.000/year – for this. From year 4 onwards we request an increase of the budget to €290.000/year in order to extend the funding to Astro-Particle Physics activities (giving us the possibility to raise the number of postdocs from 2 to 3). During the first three years the funding for the Astro-Particle Physics activities is secured via the Odysseus I grant of the corresponding group leader. As the postdocs are internationally recruited, stipends can be used reducing their salary cost to roughly €50.000/year which is comparable to the approximately €40.000/year for a PhD student. The budget is summarized in table 2.

Year	Postdocs	PhD Students	Functioning	Total
1	2	3		
	100 k€	120 k€	20 k€	240 k€
2	2	3		
	100 k€	120 k€	20 k€	240 k€
3	2	3		
	100 k€	120 k€	20 k€	240 k€
4	3	3		
	150 k€	120 k€	20 k€	290 k€
5	3	3		
	150 k€	120 k€	20 k€	290 k€

Table 2: The budget allocation. For years 1-3 we intend to complete our GOA and the proposed budget simply reflects the approved GOA budget. From year 4 onwards the program funds the astro-particle physics activities (currently covered by an Odysseus I grant) as well implying an increase of the budget such as to cover an additional postdoc.

5 Scientific Positioning

Each group individually is well-recognized in their respective domain and strongly embedded in national and international collaborations. The groups are in addition involved in intensive regional collaboration between the VUB and the ULB (both through the IIHE and the International Solvay Institutes for Physics and Chemistry), making the Brussels region a known and internationally recognized research node and a dominating player in Belgian High-Energy Physics activities.

WP1: Collider Physics The LHC at CERN was designed to probe beyond the Standard Model and will, in the coming decade, open a window to an understanding of symmetry breaking, the gauge structure of forces, the family structure of quarks and leptons, and the search for possible new particles which may relate to dark matter candidates. The LHC experiments, and specifically the CMS experiment, are focused towards the understanding of the small scale structure of the universe and its origin. The VUB has played a leading role in this collaboration of about 3300 physicists from 183 institutions in 38 countries. VUB physicists have recently assumed important roles in the CMS collaboration, are working on key measurements in high-profile topics, and are routinely involved in the internal review of important analyses before these are made public (the LHC experiments have internal peer-review procedures). We intend to strengthen and continue playing such a role in the future. In Brussels, we also established a Tier-2 grid computing center that is used, by both IceCube and CMS collaborators from all over Belgium and the world, to analyze data and run simulations.

WP2: Astro-Particle Physics Astro-particle physics is a relatively new interdisciplinary science combining insights from the fields of particle physics, astrophysics and cosmology. The aim is to unravel the various high-energy physics processes observed in the Universe and in this neutrino astronomy is an essential ingredient. Observation of extraterrestrial high-energy neutrinos would have an enormous impact on the field of astrophysics and cosmology. It would open a completely new window on the Universe, revealing parts not accessible by other messengers and therefore neutrino astronomy is poised to yield new, unexpected discoveries. The situation could probably best be compared with the advent of radio astronomy, which also revealed a large scala of new phenomena. IceCube – involving 250 scientists from 36 institutes in 10 countries – is the world's largest and most advanced neutrino observatory, and (with its DeepCore extension) is the only neutrino detector that has a realistic chance to discover neutrinos from cosmic sources in the near future. For this, one of the most promising classes of phenomena is the so called cosmic transient events (i.e. Gamma Ray Bursts and flares of Active Galactic Nuclei). As was outlined before, our astro-particle physics group at the VUB has built up unique expertise in this area, which was underlined by an Odysseus I award of the group leader in 2009.

WP3: Theoretical High-Energy Physics The VUB theorists are experts on the study of string compactifications (in particular using worldsheet techniques), D-brane dynamics, string theory models of cosmological singularities, supersymmetry, and more recently applications of string theory to heavy ion collisions. They frequently collaborate with and recruit postdocs from world-leading institutions. The faculty members have a significant international experience and both postdocs and many of the PhD students are internationally recruited. The group is a full member of the International Solvay Institutes for Physics and Chemistry allowing them *e.g.* to run a flourishing visitor program.

Reinforcing the position of VUB High-Energy Physics Our research teams are closely connected to and synchronized with corresponding teams at the ULB, which has been a very productive symbiosis in our field for decades. On the experimental side, the Inter-university Institute for High Energies (IIHE) is an excellent example of a successful collaboration for almost 40 years now. This institute has with its 70 members a leading role in Belgium for experimental (astro)particle physics. Similarly, the VUB theorists collaborate intensely with their ULB counterparts within the International Solvay Institutes. With about 90 active researchers the Brussels ULB-VUB campus dominates the field of high-energy physics in Belgium and could potentially grow into an internationally leading center for this research. Although no official structure for an institutionalized ULB-VUB collaboration combining experimental and theoretical research exists today, the creation of a VUB high-energy physics research center is an obvious first and important step in this direction. It will make us an institute which covers the complete chain from theoretical models via phenomenology to experiments, and most importantly have these groups actively collaborate.

6 Scientific Profiling

Our research has a clear international dimension and includes strategic decisions which span over decades, hence requires a robust and diverse funding network. Therefore funding is obtained through various channels. As already mentioned, the Concerted Research Action of 1,2 Meuro is absolutely essential for the building up and running of our phenomenological group. Besides this, numerous other funding sources are addressed.
Since 2002, all 3 VUB groups participate in the IAP[2] *Fundamental Interactions* providing them with a modest but most useful budget which is almost fully used as "seed money" to attract bright foreign postdoctoral fellows (who normally during their first year at the VUB apply for an individual FWO fellowship). In addition the IAP facilitates intensive collaborations between the different high-energy physics groups in Belgium.
FWO projects used to be a major source of funding, however the dramatic budget cuts for projects and the resulting very low success rate makes this a very unsure channel for funding in the future (which we will however still actively pursue). Fortunately this can be (partially) remedied using the FWO Big Science funding line – which was started to a large extent at the urging of Flemish experimental particle physicists – of which the VUB is since years one of the leading actors. A 1Meuro budget per year will be presented for the Flemish logistic and operational costs to participate in the CMS experiment at the LHC at CERN during the period 2013-2017.
The Odysseus projects managed by the FWO is yet another channel which was successfully exploited by us leading to grants in our IceCube and CMS teams (category 1 and 2, respectively). We intend to introduce new proposals in the future rounds of this line of funding.
EU funding within FP7 is more problematic. In the past the theory group – in an international consortium consisting of 25 institutes in more than 10 different countries – secured for 12 consecutive years ample funding for research and training networks mainly used for the recruitment of post- and predoctoral fellows. Currently ITN networks within FP7 focus almost exclusively on pre-doctoral training and require a strong involvement from industry. This excludes this source of funding for our type of research, though we tried several times, unsuccessfully. Using the international ties developed using past EU funding other venues such as the prestigious "Erasmus Mundus Joint Doctorate" program (unsuccessfully yet) and ESF Research Networking Program (successfully) are actively being explored.
ERC grants – both starting and advanced – are undoubtedly the most prestigious and as a consequence extremely competitive funding sources available in Europe. Our brightest young postdocs and young qualifying faculty members are strongly encouraged to apply for starting grants (two did so in the current round). Nick van Eijndhoven – the Astro-Particle Physics group leader and an Odysseus I laureate – intends to apply for an ERC advanced grant in the near future.

[2]Inter-University Attraction Poles (IAP) are national networks of excellence.

7 Valorization and Outreach

Valorization Research in high-energy physics is curiosity driven and as such not necessarily guided by any immediate valorization goals. Nonetheless as the experimental and observational aspects of the field usually require the development of novel cutting-edge technologies a significant and often unexpected spin-off is created. Examples of this are the construction of the first capacitative touch screens (presently omnipresent in smart phones) for the SPS at CERN in 1972, the numerous applications of particle physics detector technologies in the field of medical imaging, the conception of the World Wide Web at CERN and the development and application of novel and often exotic materials and devices in electronics. The recently created Knowledge Transfer Group at CERN stimulates the technology transfer towards society. The VUB is within the IIHE closely involved in the development and roll-out of the GRID computing system. GRID or distributed computing is a sort of parallel computing which combines within a large world-wide network computing resources. For the processing of the LHC collision data the IIHE has set up a GRID computing centre on our campus with about 1.1 PB disk space and 19Tflops computing power. We are part of the Worldwide LHC Computing GRID, the largest computing GRID in the world. The GRID technology has numerous applications outside the field of particle physics, for example in earthquake simulations, financial modeling, climate modeling, etc. In the 6th framework programme (FP6) of the European Commission GRID technology was the basis of one of the largest projects, both in its research network and in terms of budget, and with a diversity of follow-up projects. With our participation to the CMS experiment it is guaranteed that we will continue to explore the GRID technology, and therefore drive the technology transfer between fundamental research and the industry.

Outreach Because outreach is a very essential aspect of "big science", we initiated media campaigns at for example the occasion of the start-up of the LHC and the completion of IceCube, and organized public events with the International Solvay Institutes for Physics and Chemistry. One of the tasks of the recently introduced proposal for an Interuniversity Attraction Pole "Fundamental Interactions"[3] is the development of an extensive website – in both national languages and English – which presents various aspects of high energy physics at the level of high school students or interested laymen. The VUB groups will develope, host and maintain the IAP website, including its broad outreach section. For several years, the coordinator of our proposed Research Centre has been the Belgian delegate in the International Particle Physics Outreach Group (IPPOG), a network of people engaged in world-wide outreach for particle physics.

[3] All experimental and theoretical groups in Belgium involved in high energy physics research have been joined in the IAP (the Belgian federal networks of excellence) *Fundamental Interactions: at the Boundary Between Theory, Phenomenology and Experiment* since 2002.

8 Human Resources Management

As the number of faculty members in comparison with the wide scope of research activities is rather limited, the role of the "middle management" (postdocs) is absolutely essential for the envisaged research (in particular for the phenomenological activities). We do have a strong tradition of hiring excellent postdoctoral fellows, mostly from abroad. The postdocs play a central role in the planning and the (daily) guidance of numerous research projects. They also introduce novel expertise and at the same time they benefit from the already existing experience at the VUB. On the other hand, the practical realization of various research projects depends crucially on the efforts of outstanding PhD students who are recruited inside and outside our country. As a consequence we intend to focus the bulk of the funding obtained through this proposal to the financing of pre- and postdocs.
All groups involved in this proposal have significant experience with international hirings. Theoretically oriented postdoctoral fellows are hired through a web based platform developed by an international consortium involving about 30 institutes from Israel to Sweden (and which includes the VUB). Every year about 350 applications are received which are carefully scrutinized and ranked, after which each institute makes their own hiring decisions. Experimentally oriented postdoctoral job openings are advertised on the widely consulted web sites of CERN, ICECUBE and INSPIRE (SLAC, Stanford university). For the recruitment of foreign PhD students we mostly rely on existing individual contacts with foreign collaborators giving us access to a significant body of very talented young scientists. Since a few years we have become successful in attracting bright young physicists from other Flemish universities as well. As a significant number of pre- and postdocs recruited on external funding will eventually apply for a personal fellowship with the FWO we maintain very high quality criteria similar to those of the FWO.
Both the supervision of the PhD students and the guidance of the postdocs are done using well established management techniques. In the experimental groups, postdocs are charged with the preparations of the analyses, the daily guidance of the PhD students, working out various theoretical models and writing of the scientific papers. The project leaders define the strategy, the individual work plans and perform the overall supervision. Regular reviews of the achieved results and progress against the work plans are held and individual readjustments are made where necessary. Definition of near and long term objectives and feedback about the current progress is achieved via weekly group meetings, whereas the progress of the different projects as a whole is reviewed yearly.
We envisage about four to five postdoctoral fellows for each of the three subgroups of which at least one should be involved with more phenomenological research activities. A similar count holds for the PhD students. In view of the other funding sources – IAP, FWO projects and individual FWO fellowships – we expect the Research Center to fund 2 (years 1-3) or 3 (years 4-5) postdocs and 3 PhD students on a yearly basis. As the postdocs are usually recruited abroad, stipends can be used reducing their salary cost to roughly €50.000/year. Counting €40.000/year for a PhD student results in €220.000-270.000 to be spent on human resources.

9 SWOT Analysis

9.1 Strengths

Our research domain (high-energy physics) is a major field in which groundbreaking discoveries can be expected within the following years. Both our theory group and our experimental groups are well-established and strongly internationally embedded: several faculty members, almost all postdocs and most PhD students have been internationally recruited. We have a strong track record of consistently obtaining important external funding. The phenomenological "glue" between our theory and experimental groups is unique in Flanders, and even internationally it is rare to see a complete chain from fundamental theory to experiment at a single institution.

9.2 Weaknesses

The number of faculty members per group is not very large. All phenomenologists are paid from grants, and have therefore temporary positions. To remedy the latter point, we are trying to attract ERC/Odysseus grantees in the area of particle phenomenology.

9.3 Opportunities

Our strong international embedding puts us in a very good position to use parallel funding channels such as ERC and Odysseus: in the recent past, we have obtained an Odysseus I as well as an Odysseus II grant. These channels make it possible to hire new faculty members despite the limited VUB funding for this. Our unique combination of theoretical and experimental research within high-energy physics attracts top PhD students from nearby universities (in addition to the often excellent international PhD students our groups were already attracting). Applications for ERC grants – both at the starting and the advanced level – will be top priorities during the coming years.

9.4 Threats

The local expertise in phenomenology we are building up may be partly lost if and when key long-term postdocs leave (*e.g.* for a faculty position elsewhere). We mitigate this risk by educating PhD students and other postdocs in this area, and by building strong ties to more established phenomenology groups nearby, in particular Fabio Maltoni's group at the UCL (Louvain-la-Neuve) which is worldwide recognized.

10 Relation with the Concerted Research Action

The current proposal is a natural consequence of the Concerted Research Action (GOA) *Supersymmetric Models and their Signatures at the Large Hadron Collider*, introduced by B. Craps, C. De Clercq, J. D'Hondt and A. Sevrin with B. Craps and J. D'Hondt as PI's. (More details on `http://we.vub.ac.be/dntk/GOA.html`). This Concerted Research Action aimed at setting up a phenomenological research activity at the VUB which provides a bridge between the experimental and theoretical groups.
Our plan is to first complete the successfully started project for which we received GOA funding, namely the establishment of a complete link between theory and collider signatures, in particular between state of the art theoretical models of supersymmetry breaking and their signatures at the Large Hadron Collider. This will take the first three years of Research Center funding (the budget requested for that period corresponds to the already assigned GOA funding). After that initial period (in which the Research Center simply replaces the GOA funding), the Research Center will evolve in the following ways:

- The supported research will evolve from the concrete GOA project to more general links between theoretical and experimental research in High-Energy Physics, reflecting the transition from project to program financing. On the one hand, Research Center funds will be used in combination with external funding to obtain as large a leverage effect as possible. On the other hand, in the spirit of our current GOA project, we will keep a strong emphasis on research that connects the various groups, in particular theoretical and experimental research.

- The Research Center will provide support for our research in the field of Astro-Particle Physics as well. During the first three years, we do not request additional funding for the Astro-Particle Physics group, since for that period this is completely covered by the Odysseus I grant of the group leader. From the fourth year onwards, we ask for an increased budget so as to allow us to also fund the links between Astro-Particle Physics and our other groups.

11 External Experts

As external experts we suggest the following leading scientists in the field of elementary particle physics and/or astro-particle physics[4].

Jos Engelen is since 1987 professor of Experimental High-Energy Particle Physics at the University of Amsterdam. He is currently the head of the NWO (the Dutch organisation for scientific research). He was the Chief Scientific Officer of CERN from 2004 through 2008. Between 2001 and 2003 he was director of NIKHEF (National Institute for Nuclear and High-Energy Physics, based in Amsterdam). He is well acquainted with physics in Belgium as he is a foreign member of the FWO commission WT2 (physics) and he was a member of the research visitation team for the VUB physics department a few years ago. He (co)authored 163 publications which received an average of 70 citations/paper and his h-index is 61.

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Heino Falcke is an experimental astro-particle physicist and currently holds the chair of the Astrophysics department at the Radboud University at Nijmegen.
Prof. Falcke is "key researcher" at the Dutch Research School for Astronomy (NOVA) where he coordinates a network of Dutch astronomers who study the extremes of the universe and the physics of black holes, neutron stars and white dwarf stars. He is also an international project scientist at the Netherlands Institute for Radio Astronomy (ASTRON), the builders of the LOFAR giant radio telescope. At the Max Planck Institute for Radio Astronomy in Bonn, Germany, he is participating in the Square Kilometre Array project, a continuation of LOFAR on a global scale.
Heino Falcke studied Physics at the Universities of Cologne and Bonn. He graduated in 1992, and received his PhD, summa cum laude, at the University of Bonn just two years later. Prof. Falcke has worked as a researcher at the Max Planck

[4]All bibliometric data was taken from INSPIRE, SLAC, Stanford. Note also that 2 of the experts are theorists; the other 3 are experimentalists. None of the submitters had any recent collaborations with the suggested referees. As a consequence, there are no joint publications except for two (in 2003 and 2006) joint publications of Prof. De Clercq and Prof. D'Hondt with Prof. Linde. However, these are two publications combining the data of all four LEP detectors (De Clercq/D'Hondt and Linde belonged to different LEP experiments) and it has a large fraction of the world's population of high-energy experimentalists as author on it (more than 1000 authors). Furthermore there is one joined publication of H. Ooguri with A. Sevrin – a faculty member involved in this proposal. However this publication dates from 1992, several years before A. Sevrin joined the VUB.

Institute for Radio Astronomy in Bonn, at the University of Maryland and at the University of Arizona. He has previously received the Ludwig Biermann Award for "best young astronomer" (2000); the Academy Prize from the Berlin Brandenburg Academy of Sciences and Humanities (2006); a Visiting Miller Professorship at UC Berkeley (2006); a European Research Council Advanced Investigator Grant (2008), and the Spinoza Award 2011 "as best Dutch scientist" for his work on the shadow of the black hole in the Galactic Center and his work on LOFAR and astroparticle physics, e.g., the radio detection of ultra-high-energy cosmic rays.

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Frank Linde is an experimental particle physicist and since 2004 the director of NIKHEF, the Dutch national institute for subatomic physics, supported by FOM. He has a broad and deep background in both accelerator experiments and astroparticle physics. He is since 1995 the project coordinator of all Dutch activities in the ATLAS experiment at LHC, in which he has played a leading role in the research and development of the precision chambers for the ATLAS muon spectrometer. As director of NIKHEF he also coordinates the astroparticle physics efforts in the Netherlands, such as the neutrino detectors ANTARES and KM3NET (analogue of IceCube in Mediterranean Sea). He is full professor in elementary particle physics at the University of Amsterdam, and also actively contributes to several large scale outreach activities. He (co-)authored 362 papers which received an average of 38,5 citations/paper and he has an h-index of 57.

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Dieter Lüst is a theoretical elementary particle physicist. He has made very important contributions to theoretical elementary particle physics ranging all the way from formal results to phenomenological applications. He currently holds the Chair for Mathematical Physics at the Ludwig-Maximilians-Universität at München where he is also the scientific director and spokesman of the Arnold Sommerfeld Center for Theoretical Physics. Simultaneously he is the director of the Max-Planck-Institut für

Physik (Werner-Heisenberg-Institut) at München. He (co)authored 186 publications which received an average of 54,5 citations/paper. He has an h-index of 55.

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Hirosi Ooguri is a theoretical elementary particle physicist who made numerous contributions to a great variety of research topics. He is the Fred Kavli Professor of Theoretical Physics and Mathematics and the Deputy Chair of Physics, Mathematics, and Astronomy at the California Institute of Technology. He is a member of the Caltech Particle Theory Group. In 2007, Ooguri helped to establish the Institute for the Physics and Mathematics of the Universe at the University of Tokyo, where he is a Principal Investigator and a member of the Scientific Advisory Committee. He is the recipient of numerous prestigious scientific prizes. He (co)authored 106 publications which received an average of 109,5 citations/paper. He has an h-index of 55.

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12 Annex I: Jorgen D'Hondt

12.1 10 most significant publications from the last 5 years

- G. L. Bayatian *et al.* [CMS Collaboration], *CMS technical design report, volume II: Physics performance*, J. Phys. G **34** (2007) 995.
- S. Schael *et al.* [ALEPH, DELPHI, L3, OPAL Collaborations], *Search for neutral MSSM Higgs bosons at LEP*, Eur. Phys. J. C **47** (2006) 547
- S. Chatrchyan *et al.* [CMS Collaboration], *The CMS experiment at the CERN LHC*, JINST **3** (2008) S08004.
- V. Khachatryan *et al.* [CMS Collaboration], *Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy*, Phys. Lett. B **698** (2011) 196
- V. Khachatryan *et al.* [CMS Collaboration], *First Measurement of the Cross Section for Top-Quark Pair Production in Proton-Proton Collisions at sqrt(s)=7 TeV*, Phys. Lett. B **695** (2011) 424
- J. Alcaraz *et al.* [ALEPH, DELPHI, L3, OPAL Collaborations and the LEP Electro-Weak Working group], *A Combination of preliminary electroweak measurements and constraints on the standard model*, arXiv:hep-ex/0612034.
- V. Khachatryan *et al.* [CMS Collaboration], *Search for Dijet Resonances in 7 TeV pp Collisions at CMS*, Phys. Rev. Lett. **105** (2010) 211801, Phys. Rev. **106** (2011) 029902
- V. Khachatryan *et al.* [CMS Collaboration], *CMS Tracking Performance Results from early LHC Operation*, Eur. Phys. J. C **70** (2010) 1165
- J. Abdallah *et al.* [DELPHI Collaboration], *Measurement of the Mass and Width of the W Boson in e^+e^- Collisions at $\sqrt{s}$ = 161-GeV - 209-GeV*, Eur. Phys. J. C **55** (2008) 1
- S. Chatrchyan *et al.* [CMS Collaboration], *Measurement of the t t-bar production cross section and the top quark mass in the dilepton channel in pp collisions at sqrt(s) =7 TeV*, JHEP **1107** (2011) 049

12.2 PhD's supervised

- Dr. Steven Lowette (defended 2007) - winner of the Best Thesis Award within the CMS Collaboration in 2008 (out of about 500 running PhD projects)
- Dr. Jan Heyninck (defended 2008) - winner of the Best Thesis Award within the CMS Collaboration in 2009 (out of about 500 running PhD projects)

- Dr. Petra Van Mulders (defended 2010)
- Dr. Joris Maes (defended 2010)
- Dr. Abideh Jafari (defended 2011)
- Dr. Maryam Zeinali (defended 2011)
- Illarilla Villella (defense foreseen in 2012)
- Alexis Kalogeropoulos (started in 2009)
- Stijn Blyweert (started in 2009)
- Michael Maes (started in 2009)
- Gerrit Van Onsem (started in 2010)
- Annik Olbrechts (started in 2011)
- Karen De Causmaecker (started in 2011)

12.3 Achievements in valorisation and technology transfer

- Belgian representative in the International Particle Physics Outreach Group since 2006
- main organisor of the Belgian press conference for the start of the LHC at CERN (2008), followed by about 30 media appearances since (television, radio, newspapers)
- provided about 50 outreach talks and several guided CERN visits to a diversity of audiences from policy makers to the general public
- several outreach articles in national magazines (e.g. EOS in collaboration with Scientific American)

12.4 Addenda

- PI of the VUB contribution within the CMS experiment at CERN (17 VUB members + several technicians)
- accumulated more then 20 different research funds (grants, budgets, travelbudgets,...)
- PI of about 4.0M euro research funds as UA+UGent+VUB promotor, plus another 1.8M euro as co-PI (only the VUB part of the budget is quoted)
- PI of the main CMS construction project for Flemish universities (ended in 2009)

- PI of a GOA research grant of 1.2M euro at the VUB (together with Ben Craps)
- responsible for the CMS Tracker Silicon Module production at the IIHE (2003-2006), coordinating a team of about 10 people including ingeneers, technicians and physicists assembling a total of 5 million euros of components (successfully completed)
- elected leader of the Top Quark Physics group of the CMS experiment of about 150 international members (2007 and 2008)
- about 228 published journal papers with 6586 citations and a resulting h-index of 32 (source: *inspire*, SLAC, Stanford University)
- about 60 internal papers within large international collaborations
- about 100 conference or workshop presentations, invited seminars
- organisor, session convenor, session chairperson, board member of diverse international conferences and workshops (eg. main organisor of the 3rd International Workshop on Top Quark Physics (130 participants, 2010), the CMS physics week in Brussels (350 participants, 2011))
- representative in or member of diverse boards: Collaboration Board CMS, Physics-Computing-Offline Institution Board CMS, Tracker Upgrade Steering Committee, Tracker Institution Board, CMS Computing management (2009-2010)
- vice-president of the VUB Physics departement (2005-2008)
- director of the VUB part of the IIHE institute (since 2011)

13 Annex II: Nick van Eijndhoven

13.1 10 most significant publications from the last 5 years

- First Year Performance of the IceCube Neutrino Telescope.
  IceCube collaboration, Astropart. Phys. **26** (2006) 155.
- Multiyear search for a diffuse flux of muon neutrinos with AMANDA-II.
  IceCube collaboration, Phys. Rev. **D76** (2007) 042008.
- On the observability of high-energy neutrinos from gamma ray bursts.
  N. van Eijndhoven, Astropart. Phys. **28** (2008) 540.
- Limits on a Muon Flux from Neutralino Annihilations in the Sun with the IceCube 22-string Detector.
  IceCube collaboration, Physical Review Letters **102** (2009) 201302.
- Measurement of the Anisotropy of Cosmic Ray Arrival Directions with IceCube.
  IceCube collaboration, Astrophysical Journal **718** (2010) L194.
- Measurement of the Atmospheric Neutrino Energy Spectrum from 100 GeV to 400 TeV with IceCube.
  IceCube collaboration, Physical Review **D83** (2011) 012001.
- Limits on Neutrino Emission from Gamma-Ray Bursts with the 40 String IceCube Detector.
  IceCube collaboration, Physical Review Letters **106** (2011) 141101.
- Time-Integrated Searches for Point-like Sources of Neutrinos with the 40-String IceCube Detector.
  IceCube collaboration, Astrophysical Journal **732** (2011) 18.
- Constraints on the extremely-high energy cosmic neutrino flux with the IceCube 2008-2009 data.
  IceCube collaboration, Physical Review **D83** (2011) 092003.
- Search for Dark Matter from the Galactic Halo with the IceCube Neutrino Observatory.
  IceCube collaboration, Physical Review **D84** (2011) 022004.

13.2 PhD's supervised

- *Anisotropy in Ultra-Relativistic Heavy-Ion Collisions*, Dr. W. van Heeringen, 1996.
- *Neutral Mesons in Ultra-Relativistic Heavy-Ion Collisions*, Dr. C. Twenhöfel, 1997.
- *Neutral Meson Production in Hot Matter*, Dr. F. Geurts, 1998.

- *Production of Direct Photons in Lead-Lead Collisions*, Dr. E. van der Pijll, 2007.
- *A search for Gamma Ray Burst Neutrinos in AMANDA*, Dr. M. Duvoort, 2009.
- Martin Casier (started august 2011).
- Lionel Brayeur (started october 2011).

13.3 Achievements in valorisation and technology transfer

Not applicable.

13.4 Addenda

- IceCube project leader at the IIHE(ULB-VUB), Brussels, Belgium, since 2009.
- Laureate Belgian Odysseus I award 2009.
- Dutch group leader within the IceCube consortium 2003-2009.
- Staffmember (exp. physics), Utrecht University, The Netherlands, 1992-2009.
  Coordinator of the Alice detector simulation and physics performance studies.
  Related to this, funding was obtained for 5 PhD positions and the corresponding infrastructure from the Netherlands Institute for Fundamental Research (FOM) and the Utrecht University. Furthermore, a grant of about 1 M€ was obtained from FOM for the design and construction of the silicon strip inner tracker system of the Alice LHC experiment.
  Concerning the neutrino astronomy efforts with IceCube, funding was obtained for 1 postdoc and 1 PhD position from the Utrecht University, in addition to the usual research infrastructure.
- CERN staff-fellow, Geneva, Switzerland, 1987-1991.
  Analysis project leader within the Delphi experiment at the LEP accelerator.
- Organiser of the General Physics Colloquium, Utrecht University, 2004-2009.
- Collaboration board member of IceCube since 2003.
- Member of the "Dutch Astronomers Association" since 2003.
- Visiting professor at the University of Cape Town, South Africa (2000, 2002) in relation with the "UCT honours programme".
- Adviser for the National Research Foundation (NRF), South Africa, since 2000.
- Member of the "Utrecht Physics Society" 1998-2009.

- Member of the "Alice Physics Board", 1995-2002.
- Joined the "New York Academy of Sciences" in 1995.
- Visiting professor at the University of Lund, Sweden (1994).
- Board member of the "Dutch Physics Society (NNV)", 1993-1997.
- Collaboration board member of Alice, 1992-1996.
- About 190 published papers in reviewed journals.
- About 100 presentations at conferences, workshops, summer schools and invited seminars.
- Organiser, convenor or board member of various international workshops.

14 Annex III: Ben Craps

14.1 10 most significant publications from the last 5 years

- Balasubramanian V, Bernamonti A, Copland N, Craps B, Galli F, *Thermalization of mutual and tripartite information in strongly coupled two dimensional conformal field theories*, PHYSICAL REVIEW D 84: 105017, 2011 Impact factor in 2010: 4.964
- Balasubramanian V, Bernamonti A, de Boer J, Copland N, Craps B, Keski-Vakkuri E, Müller B, Schäfer A, Shigemori M, Staessens W, *Holographic Thermalization*, PHYSICAL REVIEW D 84: 026010, 2011 Impact factor in 2010: 4.964
- Balasubramanian V, Bernamonti A, de Boer J, Copland N, Craps B, Keski-Vakkuri E, Müller B, Schäfer A, Shigemori M, Staessens W, *Thermalization of Strongly Coupled Field Theories*, PHYSICAL REVIEW LETTERS 106: 191601, (2011) Impact factor in 2010: 7.621
- Craps B, Evnin O, *Adiabaticity and emergence of classical space-time in time-dependent matrix theories*, JOURNAL OF HIGH ENERGY PHYSICS (01): Art. No. 130 JAN 2011 Impact factor in 2010: 6.049
- Bernamonti A, Craps B, *D-brane potentials from multi-trace deformations in AdS/CFT*, JOURNAL OF HIGH ENERGY PHYSICS (08): Art. No. 112 AUG 2009 Impact factor: 6.019
- Craps B, De Roo F, Evnin O, Galli F, *p-branes on the waves*, JOURNAL OF HIGH ENERGY PHYSICS (07): Art. No. 058 JUL 2009 Impact factor: 6.019
- Craps B, Hertog T, Turok N, *A multitrace deformation of ABJM theory*, PHYSICAL REVIEW D 80: 086007, 2009 Impact factor: 4.922
- Craps B, De Roo F, Evnin O, *Can free strings propagate across plane wave singularities?*, JOURNAL OF HIGH ENERGY PHYSICS (03): Art. No. 105 MAR 2009 Impact factor: 6.019
- Craps B, De Roo F, Evnin O, *Quantum evolution across singularities: the case of geometrical resolutions*, JOURNAL OF HIGH ENERGY PHYSICS (04): Art. No. 036 APR 2008 Impact factor: 5.375
- Craps B, Evnin O, *Quantum evolution across singularities*, JOURNAL OF HIGH ENERGY PHYSICS (04): Art. No. 021 APR 2008 Impact factor: 5.375

14.2 PhD's supervised

- Frederik De Roo, defended 1 July 2010
- Wieland Staessens, defended 27 June 2011

- Alice Bernamonti, defense expected May 2012
- Federico Galli, started October 2008
- Bettina Oexl, started November 2010
- Joris Vanhoof, started October 2011

14.3 Achievements in valorisation and technology transfer

Not applicable

14.4 Addenda

- Frans Van Cauwelaert prize 2009, for his work on string theory models for the very early universe. This prize (with a value of 7500 euro) is awarded by the Royal Flemish Academy of Belgium for Science and the Arts, once every four years in the domain of exact sciences, to a Belgian author under the age of 40.
- Postdoc experience at University of Chicago (2000-2003) and University of Amsterdam (2003-2005)
- PI of a concerted research action (GOA, jointly with Jorgen D'Hondt, 1.18 M€), PI and co-PI of FWO projects, promotor and co-promotor of FWO Aspirant PhD students, promotor Solvay PhD fellowship, contributed to writing of successful IAP-project and successful NSF collaborative research grant, promotor of a project of the VUB Research Council.
- Total volume of grants obtained as PI: €1,578,250 + 3 four-year PhD fellowships.
- Total volume of grants as (official or de facto) co-PI : €950,000 + 12 postdoc years + 1 four-year PhD fellowship.
- Author of 40 scientific papers in theoretical high energy physics, including 32 in international journals with peer review, 1021 citations, $h = 17$ (source: Inspire, SLAC, Stanford, November 2011). Also an article in photonics in an international journal with peer review.
- Invited lecture series at the THEP AIO/OIO school of the Dutch Research School in Theoretical Physics (2010), at the Cyprus workshop of the Superstrings RTN network (2008), at the CERN school of the ForcesUniverse RTN network (2006) and at the String Steilkurs at the MPI Golm (2005); 2 lecture series at the Amsterdam-Brussels-Paris doctoral school
- About 25 other invited talks at international conferences and workshops
- More than 60 invited seminars and colloquia

- Project referee for the Swiss National Science Foundation and the Fonds de la Recherche Scientifique (Belgium). Referee for Journal of High-Energy Physics, Nuclear Physics B, Physics Letters B, Classical and Quantum Gravity, Physical Review Letters, Physical Review D, Journal of Cosmology and Astroparticle Physics.
- Organizer of 7 international workshops and 4 international doctoral schools
- Chairman of the VUB Physics Department (2009 - 2012)
- Assistant to the Director and Member of the Local Scientific Committee, International Solvay Institutes for Physics and Chemistry (2007 - present)

15 Annex IV: Micro CV's of other core faculty members involved

15.1 Freya Blekman

- Joined the VUB team in 2010 as research professor working on the Compact Muon Solenoid, expertise in top quark physics, b quark identification and particle physics tracking detectors.
- PhD at the NIKHEF, Amsterdam. Postdoctoral research positions at Imperial College London (2005-2007) and Cornell University (2007-2010).
- Recipient of a FWO Odysseus II grant, consisting of an amount to 867,100€ spread over five years.
- Invited lecturer at 5 hep-ex training programs including schools at Fermilab, CERN and the Turkish Atomic Agency.
- About 15 invited talks at international conferences and workshops
- About 20 colloquia and invited seminars
- (Co)authored 255 publications which received 9.841 citations and resulting in a Hirsch index $h = 47$ (source: Inspire, SLAC, Stanford University).
- Member organizing committee CMS Physics week 2011
- PR responsible of VUB Physics Department.

15.2 Catherine De Clercq

- Master in physics at the University of Gent (1973), PhD in phyiscs at the University of Brussels (1981), FWO Research Director (till 2000), currently hoofddocent.
- Paid associate at CERN (1989-90).
- Present research area: experimental astro-particle physics.
- Previous research area: experimental particle physics at colliders (LEP, SppS).
- PI and co-PI of numerous grants from the VUB, the IWT, the FWO and the Belgian federal government.
- 408 papers with a total of 16200 citations and h=62 (Inspire, SLAC, Stanford); 14 papers with 100 or more citations.
- Gave numerous talks and lectures, organized several workshops, conferences and schools.

- co-director of Interuniversity Institute for High Energies, IIHE(ULB-VUB) 2003-11.
- Member of several science policy bodies, e.g. ASPERA governing board, ApPEC Steering Committee.
- Member of several advisory boards, e.g. chair of FWO expert panel WT2, member of the FNRS expert panel C63, of the European Stategy Preparatory Group of CERN council, of the NIKHEF Scientific Advisory Committee.
- VUB PI in the IceCube collaboration.

15.3 Alexander Sevrin

- PhD from the University in Leuven (1988); from 1988-1994 postdoctoral research positions at the Institute for Theoretical at the State University of New York at Stony Brook, the Physics Department of the University of California at Berkeley and the Theory Division at CERN, Geneva.
- Since the end of the 1994 tenured faculty at the VUB, currently full professor. Founder and leader of the Theoretical High Energy Physics Group at the VUB.
- Research topics: theoretical elementary particle physics, string theory, supersymmetric field theories.
- (Co)authored 73 publications which received 1.908 citations and resulting in a Hirsch index $h = 26$ (source: Inspire, SLAC, Stanford University).
- Member of the scientific committee of numerous international conferences, workshops and schools such as the yearly CERN Winter School on Supergravity, Strings, and Gauge Theory, the premier European school in this field.
- Deputy Director of the International Solvay Institutes for Physics and Chemistry.
- Member of the Bureau of the Research Council of the VUB. Member of the Senate of the VUB.
- Member of the Board of Directors of several foundations and organizations such as the Francqui Foundation, the Vlaamse Wetenschappelijke Stichting, the Belgian Physical Society and the Belgian National Committee on Pure and Applied Physics.

16 Annex V: Publications and PhD's

A full list of the publications and PhD's originating from the three groups involved for the period 2006 - August 2011 is given in a separate file (`HEP-pubs-phds.pdf`). The source for the publication list was the VUB R&D database.