Registration form (basic details)

1a. Details of applicant

-Title: Dr.
-First name: Michel
-Initials: G.
-Prefix:
-Surname: Herquet
-Male/female: Male

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-Website (optional): http://www.nikhef.nl/pub/theory

1b. Title of research proposal

From theory to events in the LHC experiments within hours.

1c. Summary of research proposal

(max. 300 words, plus max. 5 KEYWORDS)

The Large Hadron Collider experiment will offer a unique opportunity to answer fundamental questions about the structure of the theory that describes high energy interactions at the TeV scale. However, extracting new physics imprints from the LHC data will be an enormous challenge, for experimentalists and theorists alike. A major difficulty is the time it takes to translate a theoretical idea into a realistic Monte-Carlo simulation of its experimental consequences. Fortunately, the recent development of new simulation tools, some of which I developed myself, will allow for important progress towards overcoming this problem. I propose a unified framework that will dramatically reduce the amount of error-prone technical steps that are needed to bridge the gap between theory and its experimental manifestation. This process will then take a few hours only, instead of months or years of painstaking labour.

In the context of these new developments, I propose research along two axes. First, I intend to develop new simulation tools, and extensively validate and improve the existing ones. This will enable new approaches to complex problems which are currently restricted by technical complications. Second, I want to seize the unprecedented opportunity to use these new methods and tools in concrete applications. This will greatly extend my previous work on the phenomenology of possible new physics signatures at hadron colliders.

Keywords: High Energy interactions, Phenomenology, Monte-Carlo simulation, Physics beyond the Standard Model, Hadron colliders

1d. Host institution (if known)

Nikhef

1e. NWO Division:

ALW	
CW	
EW	
GW	
MaGW	
ZonMw	
N	X
STW	
Interdivisional	

1f. NWO Domain

Alfa-Gamma	
Beta	X
Life Sciences	

Research proposal

2a. Scientific/Scholarly quality

Background and research topic

The coming decade will be an exciting era of modern high energy physics. Run II at the Tevatron collider is now underway and will produce more than fifty times the amount of data that was used in discovering the top quark, and the Large Hadron Collider has already passed successfully the injection tests in September 2008. First LHC events are expected for July 2009. The study of hadron collisions at the *TeV scale* will provide us with a unique chance to answer a long standing fundamental question: What is the exact nature of the mechanism responsible for the observed electroweak symmetry breaking? In particular, it will allow us to draw definite conclusions about the existence of the Higgs particle predicted by the successful Standard Model (SM) of particle physics.

The TeV scale.
The TeV energy unit corresponds to roughly 10^{-7} Joules, not much more than the kinetic energy of a flying mosquito. However, in high energy hadron colliders, this tiny amount of energy is concentrated in a volume almost 10^{40} times smaller. The resulting energy density is comparable to that observed at the very beginning of our universe, 10^{-12} s after the big bang. Modern colliders thus allow us to probe directly the fundamental mechanisms at play just after the birth of our universe.

Various theoretical and observational considerations suggest that particle and symmetry content synthesized in the SM may not be the full story. The so-called "hierarchy problem", in particular, implies that new physics should show up around the TeV scale in order for the Higgs boson mass not to be unnaturally fine-tuned. Though the nature of this "new physics" is still to be determined, it is probably closely linked to already known heavy particles like the W and Z bosons or the top quark. Recent experimental results that cannot be accommodated by the SM, like non-zero neutrino masses and the large amount of dark matter inferred from astrophysical observations, may be important hints for the presence of unknown particles and interactions, close to the electroweak scale of about 0.1 TeV.

However, extracting new physics imprints from existing and forthcoming hadron collider experiments, is going to be a real challenge, both from the theoretical and the experimental point of view. This is due, in part, to the enormous amount of data to be analysed, but also to the intrinsic complexity of hadron collisions. In particular, any definitive identification of "Beyond the Standard Model" (BSM) signatures will directly rely on an accurate characterization of the signature itself in order to define winning strategies to isolate it, and to subtract the potentially large underlying background.

Parton-level Monte-Carlo simulations
High energy Monte-Carlo event generators first produce "parton-level" events. They correspond to the specification of all the four-momenta associated with the final state "partons", which are fundamental particles like quarks, gluons, leptons, photons, … These variables are statistically distributed, according to known scattering amplitudes and initial state parton kinematics, which, in turn, are described by experimentally determined "parton distribution functions".

The accurate numerical simulation of both signal and background events using Monte-Carlo techniques has been a very active field of research for the past twenty years. Multi-purpose event generators based on *parton shower* techniques have

Parton shower and Matrix Element based simulations

Parton shower based generators simulate high energy events using "chains" of successive decays and radiation emissions. This method is intrinsically efficient to describe soft and/or collinear emissions of partons, and is easily interfaced with hadronization models. However, it fails to reproduce particular features of hard scattering processes. These features are better described by exact matrix elements generated using standard perturbative quantum field theory techniques, e.g. Feynman diagrams (see Fig. 1). Merging these two approaches inside a consistent framework framework is the subject of much current research because it allows to take advantages from both techniques.

been successfully used to simulate various type of high energy interactions at the LEP, HERA and Tevatron colliders. More recently, *parton-level event generators* based on leading order and next-to leading order *matrix elements* have also been used in order to refine the description of the hard core of scattering processes. Most of these tools were initially developed to simulate SM events. Occasionally a small set of BSM interactions were implemented. This was mainly done through manual, time-consuming and error-prone modifications of core source files by expert users, who traded off standardization and generality against efficiency of the resulting code.

The MadGraph/MadEvent v4 project, in which I am currently involved, started at the beginning of 2006. It followed the earlier development of the MadGraph program, which was the first tool to automatically generate Feynman diagrams (see Fig. 1) along with the associated tree-level helicity scattering amplitudes for arbitrary processes. Related to this was the development of the MadEvent Monte-Carlo generator, which makes use of the matrix elements produced by MadGraph to truly simulate parton-level events. The goal of this project was to extend and improve the "core" software to make it much more useful for both the theoretical community (by adding the possibility to easily implement new models) and the experimental community (by creating interfaces to standard parton shower and hadronization packages). In addition, both the user interface and the internal structure of the software have been significantly improved. However, the implementation of complex New Physics models was still a difficult task, mainly due to the large number of lengthy algebraic expressions to be derived.

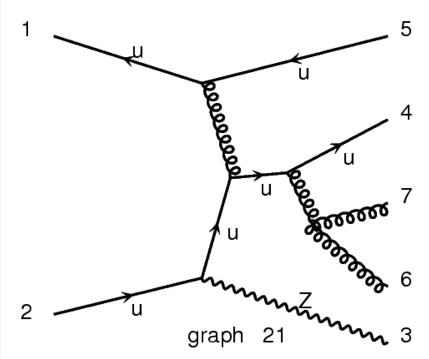

Fig. 1. One Feynman diagram generated automatically by MadGraph, among the 36320 required for the accurate simulation of a Z boson plus four jets event.

This last difficulty has recently been overcome thanks to development of the package FeynRules. This package, and the corresponding MadGraph/MadEvent v4 interface which I co-developed, allows the user to automatically generate the Feynman rules associated to an arbitrary theory in a format directly readable by the Monte-Carlo code. This completes a fully automatized chain of tools that provides high energy physicists with a fast and almost effortless road from the model Lagrangian to the fully reconstructed event as observed in a detector (see Fig.. 2).

The original software, as well as the more recent version 4 and the numerous peripheral tools already developed to date, have been enthusiastically welcomed and are now used on a regular basis by over a thousands high energy physicists. Further testimonies to this fact are the number of paper citations, personal acknowledgments and invitations of the author to speak, as a PhD student, at international workshops, conferences, and even lecture at schools.

Here I propose to apply, improve and extend the described framework to enable new studies of complex BSM signatures.

Approach and innovation

I propose research in two directions. First, I want to extensively test and even improve the tools described in the previous section as well as develop new ones, this to enable new approaches previously restricted by technical considerations. Second, I want to apply these tools to the phenomenological study of “exotic” BSM high energy theories. Such theories are still poorly or only partially studied due to the lack of adequate techniques.

Validation, improvement and development of new tools

Recently developed tools, such as new model libraries produced with the FeynRules package, or the USRMOD v2, a user-friendly interface to quickly implement small modifications to a specific model, will first need to be validated for “real-life” use. This can be done by a systematic comparison of results with those available in the literature, but also by implementing new procedures to check internal consistency.

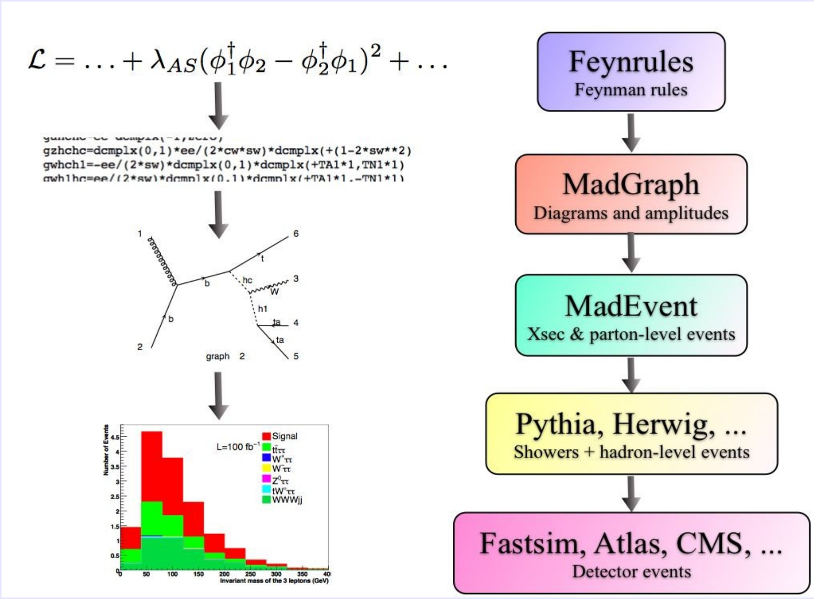

Fig. 2. Illustration of the software chain allowing high energy physicists to quickly go from a theoretical idea, i.e. a Lagrangian, to its experimental signature, i.e. reconstructed events in a detector. Intermediate steps that can now be automatically dealt with, like Feynman rules and Feynman diagrams, are also displayed.

The improvement of the existing software, and the development of new publicly available codes, is also part of this research proposal. This is because I foresee that the MadGraph/MadEvent platform will ultimately be used as a tool to develop ambitious new projects, such as including automatic calculations of NLO corrections. The platform must also be able to respond to the new needs and constraints driven by the generalization to arbitrary theories, and to the increasing demand of the experimental community for fast, robust and stable softwares. Part of the existing code, such as the Feynman diagram generation routines, should be redesigned, as a preamble to a possible deep restructuring of the whole suite.

Application of existing and newly developed techniques to phenomenological studies at hadron colliders

The existing and future tools presented in the previous sections will clearly provide us with unparalleled opportunities for new, concrete applications.

For the first time, it is conceivable the accurate simulation of new physics signatures together with the associated SM background can be handled inside a unified framework within a very limited time scale of hours, as opposed to months or years. This exciting prospect is in reach by automatizing considerably the large amount of technical (and often error prone) steps between an original theoretical or phenomenological idea and the actual realistic simulation of its experimental consequences at hadron colliders. This, in turn, opens the door to numerous possibilities for extensive, genuine collaboration between theorists and experimenters.

In particular, the phenomenological analysis of signatures from specific models with more than one Higgs boson will be achieved and possibly extended, while new ones will be defined in collaboration with theoretical (e.g, for simulating signatures of particular “Little Higgs” models, or of exotic theories falsifying string theory) and experimental groups (e.g, for the accurate simulation of unusual new physics signatures in the ATLAS detector).

Research plan

Year 1: Continuation of on-going projects, in particular the phenomenological study of unusual Higgs boson signatures at the LHC, and publication of the results. Beginning of new collaborations for BSM signatures simulations with both theoretical and experimental groups, possibly related to string theory, Little Higgs or technicolor-like models. Validation of recently developed tools and definition of a road map of possible code improvements, in cooperation with internal and external developers as well as with the user community.

Year 2: Completion and publication of results for the phenomenology projects started during year 1. Direct collaboration with experimental groups for the first LHC data analysis, especially to explain possible early signs of discrepancy with the Standard Model. Actual development, improvement and test of tools as proposed in the road map defined during year 1.

Year 3: Intensive collaboration with experimental and theoretical groups to reveal possible BSM signatures in the LHC data, with specific emphasis on unusual interpretations, i.e., involving “exotic” models still poorly studied, and solid understanding of SM backgrounds. Application of all the available tools previously designed and tested will be required to achieve this goal.

Continuously: Support and maintenance of the developed tools, and support for short “one-shot” projects emerging from the high energy physics community. Promotion of the obtained results through personal participation to international workshops and conferences.

Collaborations

The proposed project will lead to interdisciplinary collaborations. One of our main goals will be to "build bridges" between existing groups with expertise in theoretical physics and model building, and in experimental techniques and collider data analysis.

The host institution Nikhef provides an excellent environment to achieve my aim. It has a strong theory group with an important expertise ranging from string theory to top quark physics and next-to-leading-order calculations, as well as strong experimental groups active in data analysis of a variety of experiments at the LHC.

At the international level, existing collaborations with groups and individuals at UCLouvain (Belgium), UIUC (USA), SLAC (USA) and CERN (Switzerland) will continue, while other ones will of course also be envisaged for specific projects.

2c. Number of words used: 1904

2e. Literature references

[1] T. Stelzer and W. F. Long, "Automatic generation of tree level helicity amplitudes", Comput. Phys. Commun., vol. 81, pp. 357–371, 1994.

[2] Fabio Maltoni and Tim Stelzer, "MadEvent: Automatic event generation with MadGraph", JHEP, vol. 02, pp. 027, 2003.

[3] J. Alwall, P. Demin, S. de Visscher, R. Frederix, M. Herquet, F Maltoni, T. Plehn, D. Rainwater, and T. Stelzer, "MadGraph/MadEvent v4: The New Web Generation", JHEP, vol. 09, pp. 028, 2007.

[4] J. Alwall, P. Artoisenet, S. de Visscher, C. Duhr, R. Frederix, M. Herquet, O. Mattelaer, " New Developments in MadGraph/MadEvent.", Plenary talk at 16th International Conference on Supersymmetry and the Unification of Fundamental Interactions (SUSY08), Seoul, Korea, 16-21 Jun 2008.

[5] J. M. Gerard and M. Herquet, "A twisted custodial symmetry in the two-higgs-doublet model", Phys. Rev. Lett., vol. 98, pp. 251802, 2007.

[6] J. Alwall, R. Frederix, J.-M. Gerard, A. Giammanco, M. Herquet, S. Kalinin, E. Kou, V. Lemaitre, and F. Maltoni, "Is Vtb=1?", Eur. Phys. J., vol. C49, pp. 791–801, 2007.

Websites:

[1] http://madgraph.phys.ucl.ac.be: example of a MadGraph online server

[2] http://cp3wks05.fynu.ucl.ac.be/twiki/bin/view/: the MadGraph collaboration Wiki

[3] http://feynrules.phys.ucl.ac.be: the FeynRules project

Introductory literature:

[1] A. Parker, "Expedition to inner space", Physics World, October 2006

[2] J. Ellis, "Beyond the standard model with the LHC", Nature 448, 297-301, 2007.

[3] F. Maltoni, "Monte Carlo's for the LHC", Lecture notes, http://cp3wks05.fynu.ucl.ac.be/twiki/pub/Physics/HEPTOOLS08/maltoni_lectures.pdf

Cost estimates

3a. Budget

Staff costs: (in k€ incl. surcharge)							
	FTE	nr of months	200y k€	200y+1 k€	200y+2 k€	200y+3 k€	TOTAL k€
Applicant	1	36	59	60	62		181
Non scientific staff (NWP)	FTE	nr of months	200y k€	200y+1 k€	200y+2 k€	200y+3 k€	TOTAL k€
academic level							
HBO/Bachelor-level							
MBO/Foundation Degree-level							
Non staff costs: (k€)			200y	200y+1	200y+2	200y+3	TOTAL
Give a description of the non staff cost, as detailed as possible							
Computer equipment			20	10	9		39
Travel and subsistence			10	10	10		30
TOTAL			89	80	81		250

A substantial part of the grant will be invested in the computer equipment (server, cluster nodes, storage solutions, personal computer, ...) required to develop, maintain and operate the existing and future tools described in the proposal.

3b.Indicate the time (percentage of fte) you will spend on the research
100%

3c. Intended starting date
September 1st 2009

3d. Have you requested any additional grants for this project either from NWO or from any other institution? no

Curriculum vitae

4a. Personal details

Title(s), initial(s), first name, surname:	Dr. Michel G. Herquet
Male/female:	Male
Date and place of birth:	Frameries, Belgium, March 16th 1982
Nationality:	Belgian
Birth country of parents:	Belgium

4b. Master's ('doctoraal')

University/College of Higher Education:	Université de Mons-Hainaut, Mons, Belgium
Date (dd/mm/yy):	June 30th 2003
Main subject:	Theoretical Physics

4c. Doctorate

University/College of Higher Education:	Université catholique de Louvain, Louvain-la-Neuve, Belgium
Date (dd/mm/yy):	September 12th 2008
Supervisor ('Promotor'):	Prof. Jean-Marc Gérard
Title of thesis:	The two-Higgs-doublet model: From a twisted theory to LHC phenomenology

4d. Use of extension clause
(see Notes): no (if 'yes', give reasons and calculation)

4e. Current employment
- Type of contract:

Current position	Fixed term	Permanent
PostDoc	X	
Assistant professor (UD)		
Associate professor (UHD)		
Full professor (HGL)		
Other, please specify:		

4f. Work experience since graduating
(per appointment: fte, permanent position ('vast') / fixed-term ('tijdelijk')

Oct. 2008 – now: FOM 2 years PostDoc position at the Nikhef institute. Tijdelijk.

4g. Man-years of research
5 months.

4h. Brief summary of research over the last five years (maximum 250 words)

My research interests over the last five years have been mainly oriented towards the phenomenology of beyond the Standard Model (BSM) theories. In this context, I have developped, with my collaborators at UCLouvain, a particular extension of the minimal Higgs scalar sector implemented in the Standard Model of strong and electroweak interactions. This extension, which is a specific, "twisted", realisation of the generic two-Higgs-doublet model, is motivated by a relative phase in the definition of the phenomenologically successful CP and custodial symmetries. Considering extensively various theoretical, indirect and direct constraints, this model appears as a viable alternative to more conventional scenarios like supersymmetric models, and gives grounds to largely unexplored possibilities of exotic scalar signatures at present and future collider experiments.

In parallel to this specific study, I have also been centrally involved in the development of a new Monte-Carlo tool, called MadGraph/MadEvent v4. In particular, I participated to the creation of a new structure to allow users to easily implement arbitrary BSM theories in a complete chain of powerful simulation tools, and to the actual implementation of the generic two-Higgs-doublet model inside this new framework.

4i. International activities

International seminars, talks and lectures

•*Exotic two-Higgs-doublet model & associated signatures at the LHC,* talk, June 2008, Theory meeting, Nikhef, The Netherlands
•*MG/ME for photon physics at the LHC,* talk, April 2008, High energy photon collisions at the LHC Workshop, CERN, Switzerland
•*A Les Houches Interface for BSM Generators,* talk, March 2008, MC4BSM Workshop, CERN, Switzerland
•*MadGraph/MadEvent v4: Building bridges between theory(ies) and experiment(s),* talk, February 2008, ATLAS MC group, CERN, Switzerland
•*MadGraph/MadEvent v4: Building bridges between theory(ies) and experiment(s),* talk, February 2008, LCG, CERN, Switzerland
•*MadGraph v4.1: Hands-on session,* lectures, January 2008, YETI 2008 (school for graduate students), Durham, UK
•*Twisted Higgs Phenomenology at Hadron Collider",* talk, November 12th 2007, EURO-GDR SUSY 2007, Bruxelles, Belgium
•*Twisting Higgs Phenomenology at Hadron Collider,* Seminars, September and October 2007, USA:

- Princeton University (Princeton, September 11th)
- University of Illinois at Urbana-Champaign (Urbana, September 13th)
- University of Chicago (Chicago, September 17th)
- Argonne National Laboratory (Darien, September 24th)
- Fermi National Laboratory (Batavia, September 26th)
- Berkeley University (Berkeley, October 1st)
- University of California at Davis (Davis, October 2d)
- Stanford Linear Accelerator (Stanford, October 3rd)

•*Introduction to MadGraph/MadEvent,* lecture given at CAPP2007 (school for graduate students), March 2007, DESY Zeuthen, Germany
•*The two-Higgs-doublet model implementation in MadGraph/MadEvent v4,* talk given at MC4BSM workshop, March 2007, Princeton, USA
•*An not so short introduction to MadGraph/MadEvent v4,* three lectures at the HELAS/MadGraph/MadEvent school, October 2006, KEK Theory division, Tsukuba, Japan
•*MadGraph/MadEvent 4.0: New tools for New Physics,* talk given at SUSY Tools 2006, June 2006, LAPTH-LAPP, Annecy, France

Attended international conferences and workshops

•LHC related workshops at YITP, Kyoto and LHC focus week meeting at IPMU, Kashiwa, March 9th to 20th 2008, Japan (scheduled)
•Monte Carlo Tools for Beyond the Standard Model Physics workshop, March 2008, CERN, Switzerland
•Les Houches 2007: Physics at TeV Colliders, June 2007, Les Houches, France
•Computer algebra and particle physics 2007, March 2007, Zeuthen, Germany
•Physics at the LHC and Monte Carlo Tools for Beyond the Standard Model Physics workshops, March 2007, Princeton, USA
•HELAS/MadGraph/MadEvent workshop, October 2006, Tsukuba, Japan
•Tools for SUSY and the New Physics workshop, June 2006, Annecy, France
•SUSY 2005, July 2005, Durham, UK

4j. Other academic activities

National talks

•*The hunt is on: Strategies, challenges and prospects for Brout-Englert-Higgs boson(s) searches at the dawn of the LHC era,* invited talk at the annual Belgian Physical Society meeting, May 2008, ULB, Bruxelles, Belgium
•*The new MadGraph/MadEvent v4: from models to detectors in one go,* invited talk, February 2007, ULB, Bruxelles, Belgium
•*Custodial symmetry in extended scalar sectors*, talk given at IAP meeting, June 2004, KUL, Leuven, Belgium

Teaching

•Teaching assistant at the UCLouvain from September 2003 to September 2008 (approx. 200h/year, from Physics for 1st year Biologists to Advanced Quantum Mechanics for 3rd year Physicists)

Outreach activities

•Master Classes in Particle Physics outreach program at UCLouvain (2004-2006)
•Two lecture sessions on Higgs Physics at the LHC for the “Samedis de la Physique” outreach program (2008)

4k. Scholarships and prizes

•Belgian Physical Society prize for the best master's thesis in 2004
•Lauréat Olympiades Belges de Physique (1999)
•Lauréat Olympiades Belges de Chimie (1998 and 1999)

4l. Publications:

International (refereed) journals

•*MadGraph/MadEvent v4: The New Web Generation*, J. Alwall (Stanford U.), P. Demin (UCL), S. de Visscher (UCL), R. Frederix (UCL), M. Herquet (UCL), F. Maltoni (UCL), T. Plehn (U. of Edinburgh), D. L. Rainwater (U. of Rochester) , T. Stelzer (U. of Illinois at Urbana-Champaign), JHEP 0709, 028 (2007), arXiv:0706.2334
•*A twisted custodial symmetry in the two-Higgs-doublet model*, J. M. Gerard (UCL) and M. Herquet (UCL), Phys. Rev. Lett. 98, 251802 (2007) arXiv:hep-ph/0703051
•*Is V(tb) = 1?*, J. Alwall (UCL), R. Frederix (UCL), J.-M. Gerard (UCL), A. Giammanco (UCL), M. Herquet (UCL), S. Kalinin (UCL), E. Kou (UCL), V. Lemaitre (UCL) and F. Maltoni (UCL), Eur. Phys. J. C 49, 791 (2007) arXiv:hep-ph/0607115
•*A new look at an old mass relation*, J. M. Gerard (UCL), F. Goffnet (UCL) and M. Herquet (UCL), Phys. Lett. B 633, 563 (2006), arXiv:hep-ph/0510289
•*Global geometry of the 2+1 rotating black hole*, P. Bieliavsky (ULB), S. Detournay (UMH), M. Herquet (UMH), M. Rooman (ULB) and P. Spindel (ULB), Phys. Lett. B 570, 231 (2003), arXiv:hep-th/0306293

Proceedings

•*The h > AA > bb$\tau\tau$ signal with vector boson fusion production of h at LHC,* N. Adam (Princeton U.), V. Halyo (Princeton U.) and M. Herquet (UCL), proceedings of the "Les Houches 2007: Physics at TeV Colliders" workshop
•*A Les Houches Interface for BSM Generators*, P. Skands (Fermilab), M. Herquet (UCL) and others. Proceedings of the "Les Houches 2007: Physics at TeV Colliders" workshop.

In preparation

•*A twisted two-Higgs-doublet model phenomenology,* S. de Visscher (UCL), J. M. Gerard (UCL), M. Herquet (Nikhef), V. Lemaitre (UCL) and F. Maltoni (UCL)

Statements by the applicant

My thesis manuscript has been approved and I will send the official declaration to NWO
(compulsory for applicants for Veni applicants who have not yet received their doctorates, to be sent by post or as pdf using the Iris system)

I endorse and follow the Code Openness Animal Experiments (if applicable)
(see Notes)

I endorse and follow the Code Biosecurity (if applicable)
(see Notes)

X **I have completed this form truthfully**

Name: Michel Herquet

Place: Amsterdam

Date: January 7th 2008

Please submit the application to NWO in electronic form (pdf format is required!) using the Iris system, which can be accessed via the NWO website (www.nwo.nl/vi). For any technical questions regarding submission, please contact the Iris helpdesk (iris@nwo.nl).