UNIVERSITA' DEGLI STUDI DI PAVIA
The University of Pavia

DOTTORATO DI RICERCA IN FISICA
Graduate Program in Physics

Student Handbook
2012-2013

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2012–2013

Graduate Program in Physics
The University of Pavia

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M. Carfora
Coordinator of the
Graduate School in Physics

Contents

Chapter 1
Introduction

Welcome to the University of Pavia Department(s) of Physics Graduate Program. The purpose of this handbook [1] is to provide you with a summary of the important information you will need as you make your way through the graduate curriculum, carry out your research and complete your thesis. The faculty and the Coordinator of Graduate Studies (CGS) encourage you to feel free to communicate frequently and freely with them, and to collaborate with your fellow students in learning the vast amount of material that you need to acquire in reaching the forefront of research. This handbook provides also an unofficial summary of some of the administrative requirements you will have to fulfill. If you encounter any errors or have any questions, please do not hesitate to contact the CGS. For more detailed administrative information please refer to the Graduate School Offices of the University of Pavia: (Via Ferrata, 1 - Pavia, opening hours: 9.30-12.00 from Monday to Friday- Fax: 0382 985996)

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[1] In order to be of help to the graduate student entering our internationalization program, the structure of this handbook is modeled on similar handbooks adopted by various graduate schools abroad, *e.g.* the handbooks of The University of Texas, Yale University, The University of California, Berkeley. We also found the instructions available by Victoria University (New Zealand) quite useful. The adaptation is not always straightforward due to the many peculiarities of our graduate school system.

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1.1 Graduate Student Representative

Each three years, the graduate students elect three representatives, who are non-voting members of the Graduate School Board. Responsibilities include: attending grad student events or otherwise being available to listen to fellow student concerns, attending meetings of the Graduate School Board, and bringing concerns to the attention of the Board. Current representatives:

Marco Benini
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1.2 Accomodation Information

Our program is a traditional graduate program and full time and residency is required for the three years of study. We expect our graduate students to live in/near Pavia and attend classes and program events. We cannot alter academic class or teaching times to accomodate students who choose to commute over long distances. The University of Pavia does have an important tradition of historical Colleges (Collegio Ghislieri, Collegio Borromeo, Collegio Cairoli, Collegio Nuovo, Collegio S. Caterina da Siena) and graduate housing can be available. At this time, we cannot offer any additional support to pay for housing; our students generally pay rent from their fellowship stipends or part-time employment.

1.2.1 University Colleges in Pavia

Contact information for finding accommodation in an historical or a modern college in Pavia:

Historical Colleges:

- COLLEGIO NUOVO - FONDAZIONE SANDRA E ENEA MATTEI, 27100 Pavia (PV) - 404, v. Abbiategrasso tel: 0382 526372 , 0382 5471 - fax: 0382 423235 website: http://colnuovo.unipv.it
- COLLEGIO GHISLIERI, 27100 Pavia (PV) - p. Ghislieri tel: 0382 3786217 , 0382 3786204 , 0382 37861 - fax: 0382 23752, 0382 23755 website: www.ghislieri.it
- ALMO COLLEGIO BORROMEO, 27100 Pavia (PV) - 9, p. Borromeo tel: 0382 3951 , 0382 395344 , 0382 395363 - fax: 0382 395343, 0382 395360 website: www.collegioborromeo.it
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- COLLEGIO UNIVERSITARIO S. CATERINA DA SIENA, 27100 Pavia (PV) - 17/A, Via S. Martino tel: 0382 375099 website: www.collsantacaterina.it
- COLLEGIO UNIVERSITARIO FEMMINILE CASTIGLIONI 27100 Pavia (PV) - 18, VIA S. MARTINO tel: 0382 27474

Modern Colleges:

- Collegio F. Cairoli, Piazza Cairoli, tel. +39.0382/23746
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- Collegio Castiglioni, Via S. Martino 18, tel. +39.0382/33518
- Collegio Giasone del Maino, Via Luino 4, tel. +39.0382/376511
- Collegio Fraccaro, Piazza Leonardo da Vinci, tel +39.0382/301371
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Further information for each of these colleges can be found on the following webpage, (mostly in Italian): http://www.edisu.pv.it/index.php?page=collegi-e-residenze-in-pavia

Chapter 2
Who's Who in the Physics Department and in the local INFN Section

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Graduate Registrar:

- *Anna Rita Mangia*
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The blue tagging signals the new graduate students admitted to the XXVIII cycle.

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- Filippo ALPEGGIANI XXVIII
- Stefano AZZINI XXV

- Gabriele BABINI XXVII
- Luca BARZÉ XXV
- Marco BENINI XXVII
- Irene BOLOGNINO XXV
- Lorenzo BORDONALI XXV CNISM
- Lucia BOSSONI XXVI CNISM
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- Valeria PROSPERI XXVII
- Elisa ROJATTI XXVIII
- Matteo ROSSI XXVI
- David SALVETTI XXVI
- Angelica SARTORI XXVI
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2.3 Graduate School Board

The graduate school is managed by a board which is charged with the following responsibilities:

- Coordination of graduate silabii and regulations
- Admission of graduate students
- Processing of graduate theses and research projects
- Conduct supervision of graduate study programmes
- General welfare and discipline of graduate students.

Actual Members of the Graduate School Board

- CARFORA Mauro (Coordinator)
- ANDREANI Lucio Claudio
- CARRETTA Pietro
- CORTI Maurizio
- D'ARIANO Giacomo Mauro
- GERACE Dario
- GIUSTI Carlotta
- LIVAN Michele
- MACCONE Lorenzo
- MARABELLI Franco
- MONTAGNA Guido
- NICROSINI Oreste (INFN)
- OTTOLENGHI Andrea
- PASQUINI Barbara
- PATRINI Maddalena
- REBUZZI Daniela Marcella
- ROTONDI Alberto

Chapter 3
Academic Requirements

3.1 Academic Requirements Overview

3.1.1 Course Requirements

4 Term Advanced Courses; 1 National (International) School on a topical research area of interest; Physics Colloquia; (Attendance on the Colloquia and Courses is compulsory for all graduate students).

Advanced Courses 4 from the following:

- 1.Teor Electromagnetic Theory
- 2.Teor Relativistic Quantum Field Theory
- 3.Teor Statistical Field Theory
- 4.Teor Quantum Information Science
- 5.Teor Selected Topics in Quantum Mechanics
- 6.Teor Strong Interactions
- 7.Teor Nuclear Structure
- 8.Teor Electroweak and QCD Field Theories
- 9.Teor Spacetime Structure, Cosmology, and Quantum Field Theory
- 10.Teor Econophysics
- 11.Teor Advanced Theory of Solids
- 12.Teor Photonics
- 13.Teor Open Quantum Systems
- 14.Teor SPECIAL TOPICS COURSE: Biophysics on Neural Signaling
- 15.Teor SPECIAL TOPICS COURSE: Topological Quantum Field Theory and Condensed Matter Systems
- 1.Exp Imaging for Biomedical Applications
- 2.Exp SPECIAL TOPICS COURSE: Ionizing Radiation and Biological Structures: Theory and Applications
- 3.Exp Spectroscopies in Condensed Matter Physics

- 4.Exp Magnetic Resonance Techniques in Solid State Physics
- 5.Exp Experimental Particle Physics
- 6.Exp Experimental Nuclear Physics
- 7.Exp Radiation and Particle Detection
- 8.Exp Information and Data Analysis
- 9.Exp Neutrino Phenomenology and Astroparticle Physics

3.1.2 Special Topics Courses

In the above list there are a number of *SPECIAL TOPICS COURSES*, these are courses including an intensive educational program, one to two weeks long, providing experience in specialized research techniques with lecture and laboratory courses in topics of current high interest. The 2012-13 Special Topics Courses are:

- Biophysics on Neural Signaling

The course is offered under the aegis of a collaboration between our graduate school and the graduate school in physiology and neuroscience. The computational problems that are solved by networks of neurons, from roughly 100 cells in a small worm to 100 billion in humans provide a number of challenging problems to physicists. Careful study of the natural context for these tasks leads to new mathematical formulations and physical modeling of the problems that brains are solving, and these theoretical approaches in turn suggest new experiments to characterize neurons and networks. This interplay between theory and experiment is the central theme of this course. The course will start from a description of the biomolecular structure of the neuronal membrane and will provide a biophysical interpretation of the processes generating electrical activity in neurons and synapses. The target is to illustrate how neurons generate information codes and how these are processed in complex neuronal networks. Topics will include: 1) Biophysical phenomena in the neuronal membrane, 2) Information in spike trains, 3) Principles of signal processing in neuronal networks.

- Topological Quantum Field Theory and Condensed Matter Systems

This is a Special Topics Course, under the terms of a CARIPLO Foundation grant, featuring a series of lectures on the interplay between topological quantum field theory (TQFT) and condensed matter systems. The arguments discussed range from the basic of TQFT to application to condensed matter system with a particular emphasis on Graphene. The course will host as a distinguished scientist in residence Prof. Alfredo Iorio from the Charles University of Prague.

- Ionizing Radiation and Biological Structures: Theory and Applications

This is an advanced course on the interaction between biological structures and ionizing radiation offered every two years. For the year 2012/13 the course will be integrated with the special topic course *Modeling radiation effects from initial physical events*, (Pavia, May-June, 2013), dedicated to learning modeling approaches and techniques in radiation biophysics and radiobiology research, from basic mechanisms to applications.

3.1.3 Additional Elective Courses

Students are strongly encouraged to attend the elective course

- 16.Teor Soft Skills for Graduate Students

This course does not belong to the course requirements but you are strongly advised to attend it. Arguments range from writing techniques for filing a proper grant request, to developing presentation skills for seminars and the like.

3.1.4 Grades and Credits

Pavia Graduate School grade format: *Honors (H); High Pass (HP); Pass (P); Fail (F)*

- For good academic standing the Graduate School strongly recommends a High Pass average.

Credits (60 for each year) for the various activities are distributed according to the following table

	Graduate Courses	Graduate Courses	Graduate Courses	Graduate Courses	Research
			Int. Grad. School	Colloquia	
1 year	8 credits	8 credits	8 credits	4 credits	32 credits
2 year	8 credits	8 credits		4 credits	40 credits
3 year				4 credits	56 credits

3.1.5 Qualifying Seminars

At the end of the first and second academic year (typically around mid October) students are requested to make a presentation, in a public forum, of a topical research argument. See subsection 3.3.5 for details.

3.2 Typical Time Line for Academic Requirements

As already stressed in Section 1.2, our program is a traditional graduate program and full time and residency is required for the three years of study. We expect our graduate students to live in/near Pavia and attend classes and program events. We cannot alter academic class or teaching times to accomodate students who choose to commute over long distances. The University of Pavia does have an important tradition of historical Colleges (Collegio Ghislieri, Collegio Borromeo, Collegio Cairoli, Collegio Nuovo, Collegio S. Caterina da Siena) and graduate housing can be available. At this time, we cannot offer any additional support to pay for housing; our students generally pay rent from their fellowship stipends or part-time employment.

Year 1:

- Choice of Thesis adviser
- Written presentation of Thesis Prospectus and plan of studies to Graduate School Board
- Start dissertation research
- 2 required advanced courses
- National (International) School on a topical research area of interest
- Physics Colloquia
- Qualifying Seminar (October)
- Written Performance Report for monitoring the student's research progress and academic performance

Year 2:

- Continue dissertation research
- 2 required advanced courses
- Physics Colloquia
- Qualifying Seminar (October)
- Written Performance Report for monitoring the student's research progress and academic performance

Year 3:

- Physics Colloquia
- Continue dissertation research and prepare dissertation draft
- Submission of written dissertation draft
- examiner's reports due after submission
- Admission to Candidacy, including written Thesis report and relation on the student's research and overall academic performance to Graduate School Board (October)
- Thesis Defense and oral examination by an external nominated committee
- Award of degree

3.3 First and Second Years

This section concerns more detailed information on the various academic requirements listed above.

3.3.1 Choosing an Adviser

Contrary to what happens in many research institutions abroad, where graduate studies have a time span of 5-6 years, here in Italy the typical time line for graduate studies is three years (with a possibility of a Petition for an Extension for 6 months or one year. However, such an extension is not covered by a corresponding extension of the Ph.D. grant). Thus, it is best thought to start exploring possible dissertation advisers as soon as possible. An adviser from a department other than Physics can be chosen in consultation with Coordinator and the Graduate School Board, provided the dissertation topic is deemed suitable for a physics PhD. It is up to you to seek out faculty and talk to them no later than your first term (i.e. by January) to discuss your interest and possibilities for collaborating. It is also important that you explore more than one subfield of physics with respect to the particular one you are fond of. There is indeed the possibility that the field of physics and the adviser you are interested in will have no opening available at the time you are ready to begin research.

3.3.2 Preparing a thesis prospectus and plan of studies

Soon after the beginning of the Graduate School Academic Year, (say between mid December and not later than January 20), each graduate student produces a thesis prospectus and plan of studies. The prospectus must be submitted to the Graduate Registrar, Mrs. Anna Rita Mangia, and it must be approved by the Graduate School Board.

The Thesis (Research) Prospectus should be viewed as a preliminary statement of what the student proposes to do in his or her dissertation and not as an unalterable commitment. The appropriate form and typical content of a prospectus inevitably vary from field to field. However a prospectus should always contain the following information:

- Student's name, Adviser's name, date.
- A statement of the topic of the dissertation and an explanation of its importance.
- What in general might one expect to learn from the dissertation that it is not known, understood, or appreciated.
- A concise (even schematic) review of what has been done on the topic in the past.

- How will the proposed dissertation differ from or expand upon previous work.
- A basic bibliography appended to this section would be appreciated.
- A statement of where most of the work will be carried out: e.g. In the laboratory of a particular faculty member; In an international laboratory (e.g. CERN); As part of an international collaboration with a specific part of the research program carried out abroad.

This part of the research prospectus should be long enough to include essential information for the proposed topics but not overly long. It should be written in a manner comprehensible to people who are not experts in your particular subfield. Four to five pages, including figures and bibliography, should be appropriate in most cases.

The plan of studies lists the courses selected by the student-see the following subsection for details.

3.3.3 Course requirements and suggested sequencing

To complete a student's undergraduate training in classical and quantum physics, students are required to take 4 graduate courses. These latter (see the list in section 3.1) are typically one-term classroom courses (to be held in the spring term), with exams administered by the lecturer of the course in question. Most graduate courses will have a lecture or seminar component. The topics of many graduate courses may vary from term to term, however our system does not permit students to repeat a course with a change in topic. Moreover, it is foolish to attend courses you have already covered elsewhere; this does not advance your skills. Two courses must be completed in the first year of graduate study and the remaining two in the second year. In both cases the final exams must be registered, with satisfactory grades (High Pass on average over the first two years is strongly advised in order to get a good record when admitted to candidacy), not later than **OCTOBER the 1st** or you will be not permitted to register for the next term.

To gain the maximum benefits from the courses our Graduate School offers it is important that students do not see each course in isolation from the other courses or research training they are taking. Responsibility lies with each student (and their adviser) to think about what research they wish to conduct, what methods might be amenable; their own methodological competency, and therefore which courses to attend. Ideally this task will be facilitated by integration with discipline-specific courses in the Physics departments and through reading and discussion. Graduate Students should take a broad view of the courses and the opportunities they offer. Their purpose is to give students an awareness of, and experience in using a wide range of research methods and concepts in Physics. This is not solely to support the development for a PhD.

3.3.4 Course enrollment procedures

Note that, according to Graduate School rules, a particular course in the list 3.1.1 is offered if and only if at least 3 students declare an intention to audit it, (this enrollment threshold can be reduced to 2 upon approval of the Graduate School Board and of the lecturer of the course in question). An audit requires regular attendance and any other obligations as stated by the course instructor. If these requirements are not met, the audit will be removed from the students record at the instructors request. It is the student's responsibility to collaborate with her/his fellow students in reaching a rapid decision on course offering. It is up to you to be proactive in seeking out fellow students wishing to audit the particular course you are interested in so as to reach the offering threshold. For assistance in enrolling in courses, students are advised to contact their graduate student representative who will prepare the Graduate Audit Form and bring it to the attention of the Graduate School Board by the enrollment deadline for the term, (mid December).

3.3.5 Qualifying seminars

The development of seminar presentation skills is regarded as an integral part of the graduate training program for a Physics PhD at Pavia University. These presentation skills are essential to student's future success as a teacher and researcher. Thus, at the end of the first and second year (October), students are requested to make a Powerpoint (or similar) presentation, in a public forum, of a topical research argument. The format of the presentation should be a talk that lasts 30 minutes (25+5 for questions). The goal of this public presentation is primarily for the students to practice communicating in a public setting, and to receive feedback about how to improve their presentation abilities. To administer and grade the qualifying seminars an ad hoc committee will be established by the Coordinator of the Graduate School. After the public presentation, the coordinator will prepare a brief report of the Board's assessment of the student's presentation, and present this to the student and Graduate School Board.
The grading will indicate performance according to the following scheme:

ACHIEVEMENT of a PASSING SCORE on the appropriate subject area:

- Appropriate mastery of Subject Area Knowledge

QUALITY of PRESENTATION according to:

(i) QUALITY of CONTENT:

- Was the mastery of the subject adequate?
- Was the message clear and accessible?
- Was the message appropriate to audience?

- Was the amount of material appropriate?

(ii) QUALITY of SLIDES:

- Were the slides clear and readable?
- Were the slides balanced, not crowded?
- Were the slides nice to see, creative?

(iii) QUALITY of DELIVERY:

- Was the speech clear and the use of English approprate?
- Were the timing and the speed of the presentation ok?
- Was there an attempt to interact with the audience?
- Was the seminar enjoyable and engaging?

N.B. With respect to the past years we have decided to change the presentation strategy. In particular, the first year presentation should be a comprehensible and concise review of the state of the art of the dissertation research field: what has been done on the topic in the past, and how will the proposed dissertation differ from or expand upon previous work.

The second year presentation is basically a dissertation progress report: a brief review of the field prior to the thesis research to provide context, a presentation of the goals and motivations of the thesis research, a description of the dissertation research progress.

Both presentations MUST be given in English: if you are not able to speak and write English fluently, you will find it very difficult to carry out your research, or write publications. You are strongly encouraged to take advantage of the English course opportunities available through our University system.

3.3.6 Taking courses outside the Physics Department

At the discretion of the CGS and with the approval of the Graduate School Board it is possible to replace one (and only one) of the required four Term Advanced courses listed in 3.1.1 with either a course taken from the *Laurea Magistrale in Physics* or with a graduate course carried out in another (Italian) Graduate School who has signed an Academic Requirements Exchange Agreement with our Graduate School.

Laurea Magistrale courses are admitted only if they were not taken while registered as a Laurea magistrale student.

In occasional circumstances, a student can take one Graduate course in a qualified research center abroad. If the student is under a co-tutorship international agreement between our Graduate School and a Graduate School in Physics in Europe then all

Term Advanced Courses can be taken abroad. In this latter case, a course certification and the corresponding grade must be submitted to the CGS and to the Graduate Registrar, (Mrs. Anna Rita Mangia).

3.3.7 Grades

The grades assigned in the Graduate School are:

- H = Honors
- HP = High Pass
- P = Pass
- F = Fail

The Graduate School strongly suggests a grade point average of HP for a student to remain in good standing.

3.3.8 Schools and Conferences

Top research institutions often organize international (traineeships) conferences on advanced research topics which provide a rich and active environment for learning and doing Physics. The traineeships generally last 1-2 weeks and offer talented university graduates an intensive learning experience under the assistance of leading scientists. Our academic program requires that graduate students must attend one National or International School of their choice during their graduate studies. Typically this is done in the first year, but it can be postponed to the second year. Financial support will be partially provided by the Graduate program (typically up to 500-600 Euro) and by research group grants.

3.3.9 Research progress and academic Performance Report

Towards the end of the first and second academic year, (and **not later than October 15**), each graduate student produces a year report. This includes a review of her/his academic performance, a description of progress to date in the research project and a discussion of future work. The report, endorsed by the student's adviser, is read by the members of the Graduate School Board, which in turn recommends to the Graduate School Offices of the University whether the student should be permitted to register for the next academic year. The report should also include a list of publications in preparation or already published (classified into: peer-reviewed journals/ proceedings, etc.). Participation of the students in summer schools and conferences that are relevant to their research topics. Thus, the issues to be addressed within the Report are:

- results of the project
- first steps / next steps within the project
- problems / setbacks encountered and possible solutions
- lectures and courses taken
- conferences attended / upcoming conferences
- publications in preparation / already published

The Report must be submitted to the Graduate Registrar, (Mrs. Anna Rita Mangia).

3.3.10 Physics Colloquia

Pavia Physics Graduate School Colloquia are held in Room A102 Aula Giulotto at 4:00 p.m. (every two) Thursday during the Fall and Spring semesters unless otherwise announced.

Our Physics Colloquia host distinguished guest speakers who highlight the forefront of ongoing research in Physics and in related fields with a one-hour presentation addressed to a general audience of graduate students. This is particularly important for first-year graduate students and let them sample the type of research they might be involved in during graduate school. For those with more definite ideas about the research they are carrying out, this gives them an excellent opportunity to sample the various research opportunities for future jobs and to talk directly with leading scientists.

Attendance on the Colloquia is compulsory for all graduate students.

3.4 Third Year and Beyond

3.4.1 Admission to candidacy

The graduate school requires all students to be admitted to candidacy by the end of the third year. Students who have completed their course requirements with satisfactory grades, pass the qualifying seminars, and have submitted an acceptable dissertation final draft are recommended for admission to candidacy. The time line for admission to candidacy is the following:

- By **September the 1st** students must submit a final draft of their dissertation which is sent, for peer review, to **TWO OUTSIDE EXAMINERS** selected by the Graduate School Board. Each outside examiner must be someone outside of

Pavia University who has had no involvement with the student's research and who can be completely objective in his/her evaluation of the dissertation. The outside examiners are usually selected by the dissertation adviser and approved by the Graduate School Board. Usually the adviser must be proactive in suggesting and contacting the examiners.

- By **October the 1st** the outside examiners must submit a written report on the dissertation draft. After the report, the Graduate School Board may ask the student to make some changes in the dissertation. These changes must be made before submission of the definitive version of the dissertation.
- By **October 10** students must submit a Research and Academic Performance Report reviewing the work done during the three years of graduate school. This report should include a succinct description of: (i) Research work; (ii) Academic performance; (iii) Complete list of publications in preparation or already published (classified into: peer-reviewed journals/ proceedings, etc.); (iv) Participation to summer schools and conferences (classified into: national/international conferences, workshops, (traineeships) schools); (v) Talks given (classified into: invited talks to conferences and workshops, contributed talks, posters; invited talks to other universities etc.). This Report must be submitted to the Graduate Registrar, (Mrs. Anna Rita Mangia).
- On the basis of the outside examiners reports and of the Research and Academic Performance Report, the Graduate School Coordinator will prepare a brief report of the Board's assessment of the student's graduate career and present this to the student and to the Graduate school Offices for the Admission to Candidacy.
- By **October 31** student admitted to candidacy must submit the definitive version of their dissertation and the Admission to the Dissertation Defense Form (this latter obtained from the University Graduate School Offices).
- Typically the Graduate School Offices require four bound copies of the dissertation-One for the Science Library, three for the members of the Defense Committee. Two electronic copies on a CD are required for the national record of graduate school dissertations.
- The Graduate School has very specific rules about the preparation of the dissertation, see Chapter 5, Section 5.4, of this handbook for examples, details, and the LaTeX template of the thesis.

3.4.2 Forming a dissertation defense committee

The University of Pavia requires a 3-member faculty committee for the dissertation defense and must be approved by the Graduate School Board. Typically, the Dissertation Committee should be made up by one tenured faculty member of the Physics Department of the University of Pavia and by two outside members who are tenured faculty outside of Pavia who have had no involvement with the student's research and who can be completely objective in their evaluation of the student's dissertation defense. Both the student's adviser, the members of the Graduate School Committe, and the outside examiners cannot enter the make-up of the committee.

These rules are superseded when the dissertation defense is under the aegis of an international co-tutorship agreement between our graduate school and a graduate school abroad.

3.4.3 Dissertation defense

Once the Defense Committee is chosen and approved by the Graduate School Board, it is the Pavia Faculty member's responsibility to set the date, time and place for the defense at a time convenient to all members of the Committee, (the Graduate School Board strongly encourages the selection of a date between mid January and the end of February). Copies of the dissertation should be given to the Defense Committee member at least a month in advance. The dissertation defense shall consist of two consecutive parts. The first part will consist of an oral presentation of approximatively 45-60 minutes in length, in the style of a research seminar. An official announcement will appear in the departmental Seminar Notices. The second part will consist of detailed questioning of the candidate by the Defense Committee. Both parts shall be open to anyone interested. A detailed analysis of the oral examination and thesis defense is discussed in Chap. 5.

3.5 Administrative Issues

3.5.1 Petitioning for Extension

A student wishing to extend his/her registration beyond the original three years terminal date must file a Petition for an Extension to the Graduate School Board (and then to the offices). A dissertation Progress Report must also be completed along with a letter to the Graduate School Board stating the reasons for needing an extension. The extension can be requested only once and for 6 months or 1 year. Note that the extension is not covered by the Graduate Study Grant.

3.5.2 Travel

Graduate students wishing to attend meetings, conferences, etc. must ask permission to the Graduate School Board, (forms are available from the Graduate Registrar Mrs. Anna Rita Mangia). There are very important considerations against traveling for official reasons without asking permission to the School. Typically it may imply a failure in coverage for health and hospitalization insurance.

3.5.3 Financial matters

Under certain circumstances, besides the graduate scholarship, extra-mural money may be available to graduate students. The sources of this extra financing inevitably may vary case by case, and it may be subjected to both administrative and academic constraints. According to the Rules and Regulation of the University of Pavia, the basic administrative constraint is that the gross extra-mural salary should not exceed the salary associated with the graduate scholarship (for students winner of a graduate scholarship), or twice the graduate scholarship salary (for students without a graduate scholarship grant). The students should inquire with the Coordinator of Graduate Studies (and the offices) to make certain they are complying with these constraints, and in any case they must ask permission to the Graduate School Board.

3.5.4 Leave of absence

Students who need to interrupt their study temporarily may request a leave of absence. There are two types of leave, personal and medical. Students facing any type of personal or health difficulties are strongly encouraged to consult with the Coordinator of Graduate Studies.

3.6 Internationalization

3.6.1 International student issues

If you are an international student, the Office of Graduate Studies of our University offers an international student service, and can be of help with questions regarding your visa and other issues that pertain to your status as an international student at Pavia.

3.6.2 Exchange programs

Our graduate school has a rich exchange program with many graduate schools worldwide. Here is an updated list:

- University of Colorado, Boulder, U.S.A.
- University of Washington, Seattle, U.S.A.
- Iowa State University, Ames, U.S.A.
- Jagiellonian University, Crakow, Poland
- Purdue University, West Lafayette, U.S.A.
- University of California, Santa Barbara, U.S.A.
- University of California, Berkeley, U.S.A.
- University of California, Santa Cruz, U.S.A.
- State University of New York, Stony Brook, U.S.A.
- University of Houston, Houston, U.S.A.
- Texas Tech University, Lubbock, U.S.A.

There is an international agreement among our graduate school and these Universities. Students from both sides may ask to enter into this international program and obtain, besides their Ph.D degree, a specific Diploma: The International Certificate of Graduate Studies.

With Universities in France or Germany we often have a co-tutorship program leading to a Ph.D degree recognized by the graduate schools involved, (*e.g.* the most recent such a co-tutorship agreements have been with the Université de la Méditerranée (Aix-Marseille II), and with The Université Catholique de Louvain (Belgium)).

Under these international programs students may spend up to 18 months abroad (with a 50% an upgrade of their monthly salary). The interested students should inquire with the Coordinator of Graduate Studies to explore the possibilities for entering such an international program.

Chapter 4
Advanced Courses

4.1 Courses

In this section we shall briefly illustrate the advanced courses offered by the Graduate School in Physics. Note that most courses are offered each two year, thus in the following list each course has a status tagging figure: OFFERED if the course in question can be activated this academic year; NOT OFFERED if the course will be activated the next Academic Year (2013/2014).

The courses also have a Coordinator(s) tagging. The coordinator is the faculty member the graduate student have to contact for further details on the structure of the course; He also has the responsibility of the organization of the course by coordinating the various instructors and the special topics seminars that may constitute an essential part of the course.

Note that a particular course in the list is offered if and only if at least 3 students declare an intention to audit it, (this enrollment threshold can be reduced to 2 upon approval of the Graduate School Committe and of the lecturer of the course in question). It is the student's responsibility to collaborate with her/his fellow students in reaching a rapid decision on course offering. It is up to you to be proactive in seeking out fellow students wishing to audit the particular course you are interested in so as to reach the offering threshold.

For assistance in enrolling in courses, students are advised to contact their graduate student representative who will prepare the Graduate Audit Form and bring it to the attention of the Graduate School Board by the enrollment deadline for the term, (mid December).

4.1.1 Electromagnetic Theory

This is and advanced course in Classical Electrodynamics. Topics will include the theory of radiation and applications of synchrotron radiation both in laboratory and in astrophysics. In order to be activated the course requires that at least three students are willing to audit it.

- Coordinator: M. Bornatici
- Instructors: M. Bornatici
- Status: OFFERED

4.1.2 Relativistic Quantum Field Theory

This is an advanced course in quantum field theory tailored on those students interested in theoretical high energy physics. Arguments range from methods in relativistic quantum field theory to particle physics phenomenology.

- Coordinator: F. Piccinini
- Instructors: F. Piccinini, G. Montagna, Seminars
- Status: NOT OFFERED

4.1.3 Statistical Field Theory

This is an advanced course in statistical mechanics. The program typically offers arguments ranging from phase transitions, critical field theory, renormalization group theory.

- Coordinator(s): B. Pasquini, M. Guagnelli
- Instructors: B. Pasquini, M. Guagnelli, Seminars
- Status: OFFERED

4.1.4 Quantum Information Science

This is an advanced course in quantum information science.

- Coordinator: M. D’Ariano
- Instructors: M. D’Ariano, C. Machiavello, P. Perinotti
- Status: OFFERED

4.1.5 Selected Topics in Quantum Mechanics

This is an advanced course on selected arguments in quantum mechanics.

- Coordinator: M. D'Ariano
- Instructors: M. D'Ariano, C. Machiavello, P. Perinotti.
- Status: NOT OFFERED

4.1.6 Strong Interactions

This is an advanced course in hadronic physics emphasizing applications in Astrophysics.

- Coordinator: M. Radici
- Instructors: M. Radici, A. Bacchetta, B. Pasquini, Seminars
- Status: OFFERED

4.1.7 Nuclear Structure

This is an advanced course in nuclear theory. Typical topics are: nuclear models, nuclear force, nuclear reaction and electromagnetic probes.

- Coordinator(s): C. Giusti, F.D. Pacati
- Instructors: C. Giusti, F. D. Pacati
- Status: OFFERED

4.1.8 Electroweak and QCD field theories

This is an advanced course on the Standard Model and beyond. Topics will include: neutrino oscillations, introduction to supersymmetry, technicolor, comparison with recent experimental data.

- Coordinator: O. Nicrosini
- Instructors: O. Nicrosini, G. Montagna, F. Piccinini, Seminars
- Status: NOT OFFERED

4.1.9 Spacetime structure, Cosmology, and Quantum Field Theory

This is and advanced course on the interplay between general relativity and quantum field theory. The argument discussed range from QFT on curved spacetimes to the analysis of the different approaches to quantum gravity.

- Coordinator(s): M. Carfora, C. Dappiaggi
- Instructors: M. Carfora, C. Dappiaggi, A. Marzuoli, Seminars
- Status: OFFERED

4.1.10 Topological Quantum Field Theory and Condensed Matter Systems

This is a Special Topics Course, under the terms of a CARIPLO Foundation grant, featuring a series of lectures on the interplay between topological quantum field theory (TQFT) and condensed matter systems. The arguments discussed range from the basic of TQFT to application to condensed matter system with a particular emphasis on Graphene. The course will host as a distinguished scientist in residence Prof. Alfredo Iorio from the Charles University of Prague.

- Coordinator(s): A. Marzuoli, D. Gerace
- Instructors: D. Gerace, A. Iorio, A. Marzuoli, S. Sanna Seminars
- Status: OFFERED

4.1.11 Econophysics

This is an advanced course dealing with methods of theoretical physics applied to economy.

- Coordinator: G. Montagna
- Instructors: G. Montagna, Seminars
- Status: NOT OFFERED

4.1.12 Advanced Theory of Solids

This is an advanced course on solid state theory. Arguments include: elementary excitations (plasmons, polaritons,...), advanced quantum treatment of electronic systems and the like.

- Coordinator: L.C. Andreani
- Instructors: L.C. Andreani, Seminars

- Status: OFFERED

4.1.13 Photonics

This is and advanced course on photonics and nanophysics. Arguments include: nanophotonic systems and methods, quantum effects in radiation-matter interaction, non-linear optics.

- Coordinator: L.C. Andreani
- Instructors: L.C. Andreani
- Status: NOT OFFERED

4.1.14 Soft Skills for Graduate Students

This course does not belong to the course requirements but you are strongly advised to attend it. Arguments range from writing techniques for filing a proper grant request, to developing presentation skills for seminars and the like.

- Coordinator: A. Bacchetta
- Instructors: A. Bacchetta
- Status: OFFERED

4.1.15 Open Quantum Systems

This is an advanced course on the analysis of analytical and numerical techniques for the study of interacting quantum systems.

- Coordinator: L. Maccone
- Instructors: L. Maccone
- Status: OFFERED

4.1.16 Biophysics on Neural Signaling

The course is offered under the aegis of a collaboration between our graduate school and the graduate school in physiology and neuroscience. The computational problems that are solved by networks of neurons, from roughly 100 cells in a small worm to 100 billion in humans provide a number of challenging problems to physicists. Careful study of the natural context for these tasks leads to new mathematical formulations and physical modeling of the problems that brains are solving, and these theoretical approaches in turn suggest new experiments to characterize neurons and networks. This interplay between theory and experiment is the central theme of this course. The course will start from a description of the biomolecular structure of the neuronal membrane and will provide a biophysical interpretation of the processes generating electrical activity in neurons and synapses. The target is to illustrate how neurons generate information codes and how these are processed in complex neuronal networks. Topics will include: 1) Biophysical phenomena in the neuronal membrane, 2) Information in spike trains, 3) Principles of signal processing in neuronal networks.

- Coordinator: E. D'Angelo
- Instructors: E. D'Angelo
- Status: OFFERED

4.1.17 Imaging for Biomedical Applications

This is an advanced course on imaging techniques applied to problems in biomedical physics.

- Coordinator: A. Ottolenghi
- Instructors: A. Ottolenghi
- Status: NOT OFFERED

4.1.18 Ionizing Radiations and Biological Structures: Theory and Applications

This is an advanced course on the interaction between biological structures and ionizing radiation. The course will be integrated with the Special Topic Course *Modeling radiation effects from initial physical events*, (Pavia, May -June , 2013), dedicated to learning modeling approaches and techniques in radiation biophysics and radiobiology research, from basic mechanisms to applications.

- Coordinator: A. Ottolenghi
- Instructors: A. Ottolenghi
- Status: OFFERED

4.1.19 Spectroscopies in Condensed Matter Physics

This is an advanced course on spectroscopical techniques in condensed matter physics. Topics will include: (i) time resolved optical spectroscopies: techniques and experiments; (ii) Nuclear Magnetic Resonance and Nuclear Quadrupolar Resonance Spectroscopies.

- Coordinator: F. Marabelli, P. Carretta
- Instructors: F. Marabelli, P. Carretta, M. Galli.
- Status: OFFERED

4.1.20 Magnetic Resonance Techniques in Solid State Physics

This is an advanced course on magnetic resonace techniques in solid state physics.

- Coordinator: P. Carretta
- Instructors: P. Carretta
- Status: NOT OFFERED

4.1.21 Experimental Particle Physics

This is an advanced course on modern particle physics with a particular attention to collider physics.

- Coordinator: D. Rebuzzi
- Instructors: C. Conta, D. Rebuzzi, A. Negri, Seminars
- Status: OFFERED

4.1.22 Experimental Nuclear Physics

This is an advanced course on experimental techniques in nuclear and subnuclear physics. The focus of the course is the study of the structure of the lightest hadrons (mesons,nucleons) in the non-perturbative QCD regime using electromagnetic and hadronic probes. Topics covered will include: (i) overview of the existing theories of the hadronic structure: quark, chiral symmetry and lattice QCD models; (ii) baryon spectroscopy experiments using elecromagnetic probes; (iii) meson spectroscopy experiments using hadronic probes.

- Coordinator: P. Pedroni
- Instructors: P. Pedroni, Seminars
- Status: OFFERED

4.1.23 Radiation and Particle Detection

This is and advanced course on the Physics of particle detectors.

- Coordinator: M. Livan
- Instructors: M. Livan, Seminars
- Status: OFFERED

4.1.24 Information and data analysis

Advanced course on data analysis.

- Coordinator(s): A. Rotondi and A. Fontana
- Instructors: A. Rotondi, A. Fontana, Seminars
- Status: OFFERED

4.1.25 Neutrino phenomenology and astroparticle physics

An advanced course in astroparticle physics. Arguments include: cosmic rays physics, satellites and Earth based experiments, introduction to high energy neutrino physics, (in particular neutrino oscillations).

- Coordinator: P. W. Cattaneo
- Instructors: P. W. Cattaneo, Seminars
- Status: OFFERED

4.1.26 Courses in Astrophysics

These are advanced courses in astrophysics held at the University of Insubria. There is an agreement between our and their graduate school according to which our students may audit one (and only one) of these courses as part of their academic requirements.

Chapter 5
PhD Examination and Thesis

The examination process is rigorous. It aims to ensure that candidates meet the highest standards of scholarship and that the degrees conferred by our Graduate School are of the highest quality.

5.1 External Examiner's Recommendations after Reading Your Thesis

As already recalled, the first stage of the examination process involves an independent review of your thesis by **TWO EXTERNAL EXAMINERS**, (see Section 3.4.1). The examiners are asked to report within four weeks and to make one of the following recommendations:

- The thesis is of high standard and fully meets the requirements of the PhD.
- The thesis is of sufficiently high standard to meet the requirements of the PhD, although it may require minor editorial changes.
- The thesis is not yet of a standard to meet the requirements of the PhD, and there are matters that must be addressed.
- The thesis is substandard with respect to the requirements of the PhD.

5.1.1 External Examiner's Report

Each external examiner sets out the grounds for his/her recommendation in a detailed report. External Examiners are asked to help the University gauge the quality of the thesis by commenting on such things as originality, critical insight and contribution to knowledge. They are also asked to provide guidance for revision and to indicate areas requiring exploration in the oral defense. Candidates may be required to make corrections and amendments to their thesis. These can be minor cosmetic changes, but sometimes candidates are required to substantially revise and resubmit the thesis.

5.1.2 Reviewing Examiner's Report

The Board of Graduate Studies is responsible for reviewing the examiners' reports and approving the admission of the candidate to the oral defense.

5.1.3 Corrections and Amendments

As stressed above, it is very common for the external examiners to ask candidates to make changes to the thesis before it is accepted. Typically, each examiner will discuss with the candidate the needed corrections and negotiate a timeframe for completing them. Please note that it is preferable that there are no spelling mistakes in the thesis. While it is unlikely that all spelling mistakes will be found, candidates are advised to remove as many as possible. You should also tidy up other minor errors and inconsistencies of presentation. Beyond the editorial corrections, examiners will frequently require that certain things are put right before you deposit the thesis in the University Library. Required changes may be small but important, such as replacing an incorrect use of a technical term or getting the notation right, or they may be major. Changes candidates are commonly required to make include:

- Rewriting a particular chapter to take account of material that has been overlooked
- Reorganising material in the thesis
- Omitting some material
- Improving or clarifying an argument

It is important to make corrections of this type before the oral defense takes place. If the changes to the candidate's thesis are substantial and likely to require more than two months full-time work to complete, the Board of Graduate Studies will require the candidate to re-submit, and to apply for an extension.

5.2 Oral Defense

The oral examination will take place usually two to three months after you have submitted your thesis for examination. As already described in section 3.4.2, the defense committee is usually formed by three examiners: one examiner is a senior and independent academic from our Physics Department, and at least two more examiners come from another Italian university; qualified experts possibly coming from

Research Institutions abroad can be members of the defense committee, as well. During the oral examination the candidate will be expected to defend his/her thesis by elaborating on his/her arguments; by explaining how his/her thesis is set in a wider disciplinary context; by discussing the implications of his/her work. The oral defense is an integral part of the examination process. The way the candidate performs in the oral will have a bearing on the overall recommendation submitted to the Vice-Chancellor (Rettore) for the fulfillment of the requirements for the PhD degree.

The Defense Committee will be chaired by the academic selected, by our Physics Department, as Committee member .

All designated external examiners must be present in the room. The overseas examiners (designated as experts) may be linked by video-conference. The candidate's adviser is expected to attend, but he/she will not take part in discussion during the oral, though he/she may make a statement to the examiners at the end of the candidate's defense. Any support people in attendance will not have speaking rights.

5.2.1 Format of the Oral

Oral examinations generally take place as follows:

- The chair will commence with a welcome and introductions of all present.
- The candidate will then have an opportunity to address the examiners for 45 to 60 minutes without interruption.
- The examiners will question the candidate on his/her thesis and engage him/her in discussion about his/her research.
- The chair may invite the candidate to make a closing statement.
- The chair will ask the candidate and any support persons or observers to leave the room.
- The candidate's adviser will be given an opportunity to make a statement to the examiners and will answer any questions the examiners wish to pose.
- The adviser will then leave the room.
- The examiners will discuss the candidate thesis and agree on what recommendation to make to the Vice-Chancellor (Rettore) of the University of Pavia.
- The chair will recall the candidate to the room, and the candidate will be advised of the examination committee's recommendation.

The whole examination should take around two hours.

5.3 Depositing Your Thesis in the Library

Theses which have been accepted for the award of a Ph.D. degree are held as part of the Physics Librarys collection, and once your examiners have agreed that your thesis meets the requirements of a PhD, you must deposit one hard-bound copy of it in the University Library along with a PDF version of reasonable file size (please contact the Director of the Library, Dr. Anna Bendiscioli: anna.bendiscioli@unipv.it, for details). Note that before depositing your thesis, you will need to complete a permission slip. Candidates should also ask to the the Library's Cataloguing Team for the ISBN code to be attributed to their thesis, (the ISBN code is required for cataloguing Graduate Theses on Deposit). The hard-bound copy of the thesis must be identical to the PDF version. Once in the Library, your thesis may be consulted, borrowed and copied in accordance with the regulations. The electronic version will published online via the ResearchArchive *http://siba.unipv.it/fisica/ScientificaActa/dottorato_online.htm*

5.3.1 Copyright

When depositing your thesis the Library's Cataloguing Team may ask if you have used any third party content. All quotations should be attributed to the source of the quotation with a proper citation as is the standard in Physics. Other third party content such as maps, images, and so on should also be attributed. When you are a university student you can often make use of third party content without getting the permission of the author or creator of that content. You can do this because copyright laws permit research uses of third party content in some circumstances. However, when you are no longer a student you may not be able to use that third party content outside of the university setting without the permission of the author or creator. Availability of your thesis in the electronic library is a potential example of where permission might be needed. In the permission slips you are asked this question about third party content so that both you and the university can be protected from allegations of copyright infringement.

5.3.2 Long abstract submission to Scientifica Acta

Candidates must submit an extended summary of the final version of their thesis to Scientifica Acta, the peer-reviewed journal published by the *Alessandro Volta* Graduate School in Science and Technology of the University of Pavia. Scientifica Acta devotes a yearly issue to these extended summaries. The typical deadline for submission is mid–november.

Instructions for submission are available at

$$http://riviste.paviauniversitypress.it/index.php/sa/index$$

(contacts: Scientifica Acta, Biblioteca Delle Scienze, scientifica.acta@unipv.it).

5.4 Printing and Binding

Candidates should select a type font that produces clear script of adequate size, (in any case not smaller than 12pt). The text must be clear and of a size that is easy to read. The thesis should be typeset using Times New Roman (or the similar). The Board of Graduate Studies accept dissertations in A4 format. However, please note that the official printed version of the PhD thesis must be in the B5 JIS $(182\,mm \times 257\,mm)$ format. You must pay all charges associated with printing and binding.

5.4.1 Cover and LateX source

While the main body of the thesis is conveniently handled in LaTeX, the cover etc. is more easily processed with Word. For your convenience we provide here the standard PhD thesis latex template we adopt in our Graduate School. The source files (word for the front pages; Latex for the main body) are available at the web page of the graduate school. The thesis is bounded in softcover. The proper layout of the cover of the thesis is described in the following figures.

UNIVERSITA' DEGLI STUDI DI PAVIA

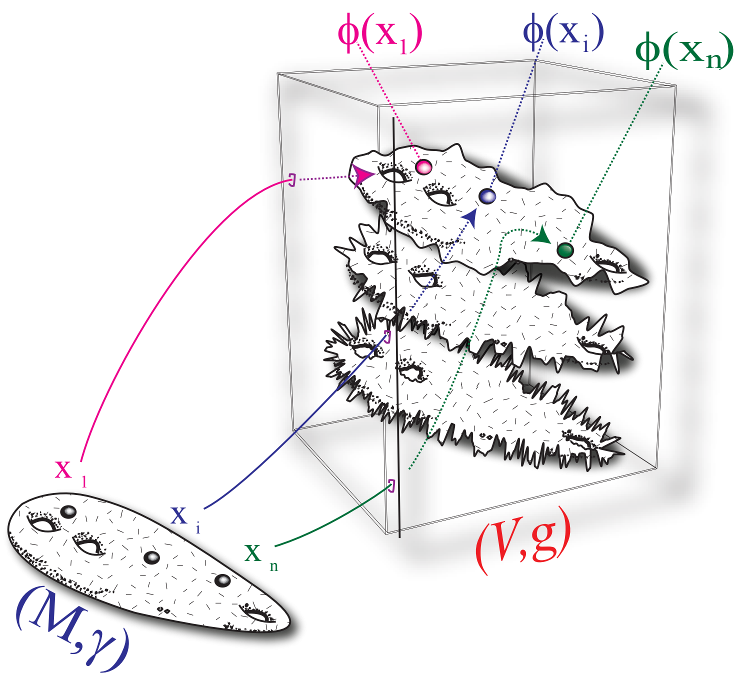
DOTTORATO DI RICERCA IN FISICA ..... CICLO

here thesis title, e.g.:

RANDOM SURFACES AND
QUANTUM GRAVITY

here name of the author:

John Fledermaus



Tesi per il conseguimento del titolo

Fig. 5.1 The front page of the PhD thesis.

Università
degli Studi
di Pavia

DOTTORATO DI RICERCA IN FISICA ..... CICLO

here thesis title, e.g.:

RANDOM SURFACES AND
QUANTUM GRAVITY

By

John Fledermaus

Submitted to the Graduate School in Physics
in Partial Fulfillment of the Requirements
for the Degree of

DOTTORE DI RICERCA IN FISICA
DOCTOR OF PHILOSOPHY IN PHYSICS

at the
University of Pavia

Adviser: ....

Fig. 5.2 The second page of the PhD thesis.

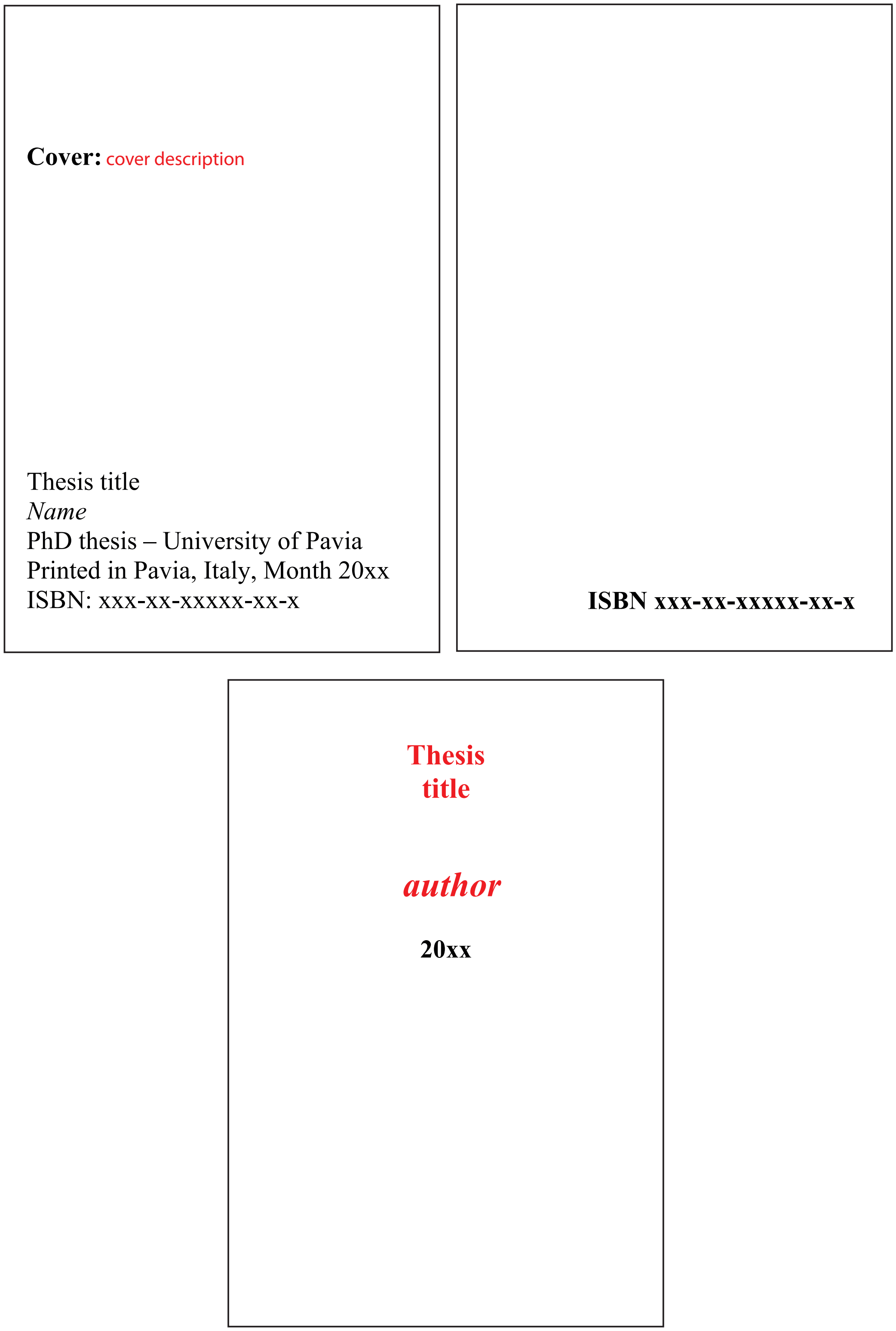


Fig. 5.3 The 3rd, 4th, and 5th page of the PhD thesis.

```
% !TeX spellcheck = en_GB
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%                                        %
%       PhDThesis.tex                           %
%                                        %
%       Dottorato in Fisica - Universitï¿½ di Pavia          %
%                                        %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

\documentclass[a4paper,12pt,twoside,openright]{book}

%-------------------PACKAGES---------------------------------------------------
\hfuzz=3pt % Don't report overfull h-boxes if over-edge is small
\vfuzz=3pt % Don't report overfull v-boxes if over-edge is small

\usepackage[all]{xy}
\xyoption{ps} \xyoption{dvips}
%\include{diagrams}

\usepackage[english, italian]{babel}
\usepackage[utf8]{inputenc}
\usepackage[T1]{fontenc}
\usepackage{ae,aecompl,aeguill} % nice pdf
\usepackage{graphicx,color,setspace,amsmath}
\usepackage{amssymb}
\usepackage{mathrsfs}
\usepackage{lscape}
\usepackage{rotating}
\usepackage{verbatim}
\usepackage{amsfonts}  % stile calligrafico in matematica
\usepackage{amsbsy}    % i simboli matematici in bold: \boldsymbol{}
\usepackage{makeidx}   % serve per fare l'indice analitico
\usepackage{textcomp}
%\usepackage{makeglos}   % serve per fare un glossario
%\usepackage{eso-pic}
%\usepackage{wallpaper}
```

Fig. 5.4 The Latex source pag.1. We wish to thank Dr. S. Azzini for making available the LaTeX template.

```
%----------------- definisco i fonts-------------------------------------------

%\usepackage{helvet} % tutti i font delle sezioni in helvetica

%inverse search for Kile
\usepackage[active]{srcltx}

\usepackage{sectsty} %cambia font nei titoli delle section: alternativo a fancy
\chapterfont{\thispagestyle{empty}}
\paragraphfont{\sl\bf}

%------------ my personal commands-----------------------------------------

\newcommand{\clearemptydoublepage}{\newpage{\pagestyle{empty}
    \cleardoublepage}}
\newcommand{\paginavuota}{\newpage\thispagestyle{empty}{\ }} % pag bianca di separazione
\newcommand{\wavenumber}{\ensuremath{\mathrm{cm}^{-1}}}
\newcommand{\textupper}[2]{\ensuremath{\mathrm{#1}^{#2}}}
\newcommand{\textdown}[2]{\ensuremath{\mathrm{#1}_{#2}}}
\newcommand{\vect}[1]{\ensuremath{\mathbf{#1}}}
\newcommand{\vrpar}{\ensuremath{\left(\vect{r}\right)}}
\newcommand{\pare}[1]{\ensuremath{\left(#1\right)}}
\newcommand{\gfrac}[2]{\frac{\textrm{\normalsize{$#1$}}}
                {\textrm{\normalsize{$#2$}}}}
\newcommand{\derpar}[1]{\gfrac{\partial }{\partial #1}}
\newcommand{\dersecpar}[1]{\gfrac{\partial^2}{\partial #1 ^2}}
\newcommand{\Derpar}[2]{\gfrac{\partial#2 }{\partial #1}}
\newcommand{\Dersecpar}[2]{\gfrac{\partial^2 #2}{\partial #1 ^2}}

%----------------------------Page Style-----------------------------------------

\addtolength{\textheight}{20mm} % allungata un po' l'altezza del testo
\addtolength{\voffset}{-10mm}   % pagina spostata verso l'alto
\setlength{\textwidth}{140mm}   % allargato un po' il testo
\setlength{\oddsidemargin}{10mm} % testo centrato nel foglio
\setlength{\evensidemargin}{10mm}
```

Fig. 5.5 The Latex source pag.2

```
%------------------header e footer -----------------------------------------

\usepackage[Lenny]{fncychap} % ï¿½ quello con il rettangolino!
\usepackage{fancyhdr}
\pagestyle{fancy}                    % usa il pacchetto fancyhdr
\addtolength{\headheight}{1.6pt}       % header un po' piu' alto
\addtolength{\headwidth}{6mm}          % header piu' largo del testo
\renewcommand{\chaptermark}[1]{\markboth{\thechapter.\ #1}{}}
\renewcommand{\sectionmark}[1]{\markright{\thesection.\ #1}{}}
\fancyhead[RE]{\sffamily \leftmark}     % pag. sinistra: capitolo sans serif
\fancyhead[LO]{\sffamily\rightmark}     % pag. destra: sezione sans serif
\fancyhead[RO,LE]{}   % header esterno: niente
\fancyfoot[C]{\thepage}    % numero di pagina al centro in basso

\renewcommand{\headrulewidth}{0.4pt}    % spessore della linea sotto l'header
\renewcommand{\footrulewidth}{0pt}      % spessore della linea sopra il footer

\ChNameVar{\fontsize{16}{14}\usefont{OT1}{ptm}{m}{n}\selectfont\bf}
%\ChNameVar{\fontsize{16}{14}\usefont{OT1}{phv}{m}{n}\selectfont\bf}
\ChTitleVar{\Huge\bfseries\rm\bf}
\definecolor{gray50}{gray}{.5} % 10% gray        %cambiano un po' Lenny
\ChRuleWidth{1pt\color{black}}
\ChNumVar{\color{gray50}\fontsize{70}{60}\usefont{OT1}{ptm}{m}{n}\selectfont\bf}

%%%% DEFINITION OF the basic rule width

% -------------------------didascalie -----------------------------------

\usepackage{caption}

\newcommand{\didascaliasu}{     % didascalia sopra la figura (per le tabelle)
   \setlength{\abovecaptionskip}{0pt}%
   \setlength{\belowcaptionskip}{9pt}%
   \caption}
\newcommand{\didascaliagiu}{%      didascalia sotto la figura (per le figure)
   \setlength{\abovecaptionskip}{9pt}%
   \setlength{\belowcaptionskip}{0pt}%
   \caption}

\hyphenation{}
```

Fig. 5.6 The Latex source pag.3

```
%=============================================================================
%   +++++ CORPO DEL DOCUMENTO +++++
%=============================================================================

%\makeindex

\begin{document}

\frontmatter
\pagenumbering{roman} \setcounter{page}{1}

%\begin{titlepage}

%\input{titlepage.tex}

%\end{titlepage}
%\paginavuota

% \usepackage[nottoc]{tocbibind} %to include explicitly Table of
                    % Contents&Co in the index
\selectlanguage{english}

%----DEDICA---------------------------------------------------------------------
%\vspace{4cm}
%\hspace{5cm}
%\begin{minipage}[c]{10cm}
%dedica
%\end{minipage}
%----DEDICA---------------------------------------------------------------------
%\paginavuota

%----INDICE---------------------------------------------------------------------

\tableofcontents

%\addcontentsline{toc}{chapter}{Table of contents}

\paginavuota
%\addcontentsline{toc}{chapter}{List of Figures}
%\listoffigures
%----INDICE--------------------------------------------------------------------
```

Fig. 5.7 The Latex source pag.4

```
\mainmatter

%\addcontentsline{toc}{chapter}{Introduction and keywords}
\include{chapter1}
\pagenumbering{arabic} \setcounter{page}{1}
%\input{introduction.tex}
%\paginavuota
\include{chapter2}
%-----------------------------------------------------------------------------
\include{chapter3}
%\input{capitolo2.tex}
%\section{First paragraph}
%\section{Second paragraph}
%\label{chap2}
%\paginavuota
%-----------------------------------------------------------------------------
\include{chapter4}
%\section{First paragraph}
%\section{Second paragraph}
%\input{chap3.tex}
%\label{chap3}

%\paginavuota
%-----------------------------------------------------------------------------
\include{chapter5}
%\chapter{Conclusions and future perspectives}
%\addcontentsline{toc}{chapter}{Conclusions and future perspectives}
%\input{conclusioni.tex}
%\paginavuota

%\backmatter
%\addcontentsline{toc}{chapter}{Index}
%\printindex
%\paginavuota
%\input{index.tex}

%\appendix
%-----------------------------------------------------------------------------
%\chapter{Appendix}
%\input{appendix.tex}

%\setcounter{secnumdepth}{-2} % per evitare che \part{Appendices} sia numerata
%\part{Appendices}
%\setcounter{secnumdepth}{2} % default
%\paginavuota
%-----------------------------------------------------------------------------

\include{biblio} % the bibliography (of the thesis)
\bibliography{biblio} % bibliografia con bibtex
\bibliographystyle{unsrt} %standard
%\bibliographystyle{abbrv}

\include{publ}
%\chapter*{List of publications} % (del dottorando: opzionale)
%\input{publ.tex}
\addcontentsline{toc}{chapter}{List of publications}

\end{document}
```

Fig. 5.8 The Latex source pag.5

Chapter 6
Research Activity

The activities of our Graduate Program reflect a spectrum of interests ranging from pure to applied Physics and include four main programs:

- NUCLEAR AND SUBNUCLEAR PHYSICS
- THEORETICAL AND MATHEMATICAL PHYSICS
- CONDENSED MATTER, OPTICAL PHYSICS, QUANTUM INFORMATION
- INTERDISCIPLINARY AND APPLIED PHYSICS

Student research is supervised by faculty in the Department of Physics, by affiliated faculty, and by members of the local section of the Italian Institute of Nuclear Physics (INFN). Refer to related departments and research centers in our links page : http://dottorato-fisica.pv.infn.it/ for information on faculty members pursuing research in the areas listed.

Here a detailed overview of Graduate Research carried out at Pavia

6.1 NUCLEAR AND SUBNUCLEAR PHYSICS

6.1.1 ATLAS

ATLAS is one of two general-purpose detectors at the LHC. It investigates a wide range of physics, including the search for the Higgs boson, the scenarios beyond the Standard Model, and particles that could be candidates for dark matter. ATLAS will record sets of measurements on the particles created in collisions - their paths, energies, and their identities. The Pavia group counts 15 people at present. It has been involved in the construction of one of the ATLAS detecting systems (the Muon Detector) and in the development of the trigger architecture. Now it is active in many different areas, from Muon Detector monitoring and data acquisition system to data analysis (Higgs boson and Supersymmetry searches). As the experiment is currently in a successful data taking period, there is a wide range of possibilities and opportunities for both diploma and PhD thesis. (Daniela Rebuzzi)

6.1.2 Standard Model Analysis

The Pavia group has been involved in the search and analysis of the ZZ-¿llvv signal, for the measurement of the cross section and the search of tri-linear gauge boson couplings. In the next year, the plans are to partecipate to the analysis of multi-parton events (two pairs of partons independently undergoing a hard scattering) in same-charge WW final states (R. Ferrari, M. Bellomo).

6.1.3 Higgs Studies

The Pavia group has been involved since several years in the Higgs studies, contributing to the Higgs discovery in the SM H-¿ZZ-¿4l channel. During the last years, it has also been active in a LHC-wide effort to calculate Higgs cross sections, branching ratios and pseudo-observables, together with their uncertainties, relevant to SM and MSSM Higgs boson(s), to facilitate comparison and combination of results (D. Rebuzzi). The Pavia group has also always taken active part to the MonteCarlo activities: generator development and maintenance, sample preparation and dataset validation (G. Polesello, D. Rebuzzi).

6.1.4 SUSY Analysis

The search for physics beyond the Standard Model, together with the measurement of the properties of the newly discovered Higgs boson, is the main goal of the analysis of the LHC data. The Pavia group has long story in the investigation of Supersymmetry (SUSY), one of the main candidates for new physics. Our analysis group (G. Polesello, G. Gaudio, P. Dondero), working in close collaboration with other Italian groups in ATLAS has a leading role in these searches. The main field of interest at present is the search for a supersymmetric partner of the top quark with the data collected in 2012 at a center of mass energy of 8 TeV, and the preparation for the data taking in 2015 at 13 TeV, which will open a new window of opportunity for discoveries. (G. Polesello, G. Gaudio)

6.1.5 Upgrade Project

The ATLAS detector data taking has been now stopped for two years time in order to allow the ordinary maintenance of the detectors and to insert new technologies under study and development through two new detectors situated in the forward regions. In this phase, the Pavia group is highly involved in the replacement of part of the Endcap Muon detector (the New Small Wheel project) at both levels of detector design and construction, using Micromegas technology (A. Lanza, G. Gaudio, R. Ferrari, M. Fraternali, M. Livan, S. Franchino), and of software related to performance studies (A. Rimoldi).

6.1.6 Trigger, DAQ

The physics results of the ATLAS experiment depend significantly on the efficiency and reliability of the trigger and data acquisition system, that is supposed to select and record the most interesting events reducing the data rate from 40 MHz to about 1 kHz. Our group participated to the design, implementation and maintenance of the current system and it is involved in the upgrade projects (P. Dondero, R. Ferrari, A. Lanza, A. Negri, V. Vercesi). The ongoing activities are: data flow system: the scheduled LHC upgrade entails new challenges for the ATLAS data acquisition system, that will have to cope with higher rates, bandwidths and processing power needs. The data flow architecture is therefore under redesign with the focus on the exploitation of the latest networking and computing technologies. FastTracker (FTK): the ATLAS upgrade project foresees a new hardware trigger, that can provide in few microseconds high-quality tracks reconstructed over the entire inner detector. FTK solves the combinatorial challenge inherent to tracking by exploiting the massive parallelism of associative memories that can compare inner detector hits to millions of pre-calculated patterns simultaneously.

6.1.7 Online monitoring

Pavia group has developed and is maintaining the core package for the online monitoring used in large part of the ATLAS experiment (that loads and runs plugins with specific detector monitoring code). Moreover the Pavia group has the responsibility for the online monitoring for the MDT detectors in the Muon Spectrometer, utilities for emulating data sampling from disk and data-acquisition monitoring libraries (G. Gaudio, R. Ferrari). There is also a strong involvement in the data quality procedure for the Muon Spectrometer detectors.

6.1.8 DREAM

DREAM During the past seven years, the DREAM Collaboration has systematically investigated all factors that determine and limit the precision with which the properties of hadrons and jets can be measured in calorimeters. Using simultaneous detection of the deposited energy and the Cherenkov light produced in hadronic shower development (dual readout), the fluctuations in the electromagnetic shower fraction could be measured event by event and their effects on signal linearity, response function and energy resolution eliminated. The Italian-US Collaboration has recently started the construction of a full containment calorimeter which incorporates all these elements and shouls make possible to measure the four-momenta of both electrons, hadrons and jets with high precision, in an instrument that can be simply calibrated with electrons. (Daniela Rebuzzi)

6.1.9 AEGIS

Does antihydrogen fall with the same acceleration as hydrogen? The principle of universality of free fall (or *weak equivalence principle*, WEP) states that all bodies fall with the same acceleration, independent of mass and composition. The WEP has been tested with very high precision for matter but never for antimatter. AEgIS is an experiment by a collaboration of physicists from all around the world to test the WEP with antiprotons at the European laboratory CERN, using the antiproton decelerator (AD).

The goal of the AEgIS experiment is a first direct measurement of the earth's gravitational acceleration with the simplest form of electrically neutral antimatter, namely antihydrogen. In the first phase a measurement of the gravity force with 1% precision will be carried out by sending an antihydrogen beam lauched horizontally in a vacuum tube and by measuring the gravitational sag with a Moiré deflectometer and a position sensitive detector.
The essential steps leading to the production of antihydrogen and the measurement of g with AEgIS are the following (for details see the experimental proposal at http://aegis.web.cern.ch):

- production of positrons (e^+) from a Na (Surko-type) source and accumulator;
- capture and accumulation of antiprotons from CERN's antiproton decelerator in a cylindrical Penning trap;
- production of positronium (Ps) by bombardment of a nanoporous material with an intense e^+ pulse;
- excitation of the Ps to a Rydberg state with principal quantum number $n = 30\dots40$;
- recombination of antihydrogen by resonant charge exchange between Rydberg Ps and cold antiprotons:

- Ps + antiproton $\longrightarrow e^- +$ antihydrogen;
- formation of an antihydrogen beam by Stark acceleration with inhomogeneous electric fields;
- determination of g in a two-grating Moiré deflectometer coupled to a position-sensitive annihilation detector.

The activities of the Aegis group of the INFN unit and of the University of Pavia are connected with the data acquisition of the apparatus, with the montecarlo simulation of the detectors used to detect antihydrogen and with the data analysis of the experiment. For further information please visit the experiment website: http://aegis.web.cern.ch/aegis/ . (Andrea Fontana, Cristina Riccardi, Alberto Rotondi)

6.1.10 PANDA

PANDA is the acronym for antiProton ANnihilation at DArmstadt. The experiment, in preparation at the GSI laboratories in Darmstadt (Germany), will exploit the annihilation of antiprotons (on protons and nuclei) to perform high precision charmonium spectroscopy. Moreover, a wide range of topics in the nuclear physics field will be addressed, such as the study of gluonic excitations and non standard bound states, meson properties in medium modification, nuclear structure and hypernuclear physics. For further information please visit the experiment website: http://www-panda.gsi.de/. Since the detector is a high precision spectrometer, a key factor is the track reconstruction capability. The Pavia group, whose participation to the project dates back to PANDA early stages, is actively involved in the realization of the Central Tracker (Straw Tube Tracker), in collaboration with Frascati, Ferrara, Jlich, Cracow and other groups. In this project, its main role is the implementation of the software related to the tracking system. Specifically, it has the responsibility of the simulation and reconstruction code for the Straw Tube Tracker. It is also involved in the implementation of the algorithms for the track reconstruction (pattern recognition, track fitting, Kalman filter). Finally, it has the responsibility of the maintenance of the track following package (GEANE), used in the Kalman filter procedure. (G. Boca, A. Braghieri, S. Costanza, P. Genova, L. Lavezzi, P. Montagna, A. Rotondi)

6.1.11 Mambo

The goal of the MAMBO experiment is the study of the nucleon and nuclear structure in the non-perturbative QCD regime. This goal is achieved, at the Mainz and Bonn tagged photon facilities, with the accurate measurement of the single and multi pion photo-production processes, both on the free and bound nucleons, in the energy region from threshold to 3.5 GeV with the use of a polarized gamma-ray beam and/or polarized targets. The broad physics program that is thus accessible includes the:

- study of the elementary and nuclear excitation of N* resonances
- search for exotic mesons and baryons
- experimental check of the Gerasimov-Drell-Hearn sum rule
- elementary and nuclear hyperon production and decays
- modifications of the nucleon properties inside the nuclear medium.

The Pavia group has been actively involved in these research activities for many years, and offers a wide range of opportunities for both diploma and PhD thesis. (A. Braghieri, P. Pedroni)

6.1.12 Physics applied to Medicine

The INFN-CNAO challenge for treatment of eye tumors, and the new hadron accelerator at the CNAO (Centro Nazionale di Adroterapia Oncologica) Laboratories in Pavia allow to investigate the feasibility of a new dedicated line for the treatment of intraocular uveal melanomas by using an active proton beam scan. The active group in Pavia studies the simulation with the Geant4 tool of the CNAO setup with the passive/active components on the expected beam-line as well as the detector, a human eye with a tumour inside. The simulation tool developed can be used to study a new design of treatment elements and to evaluate validity and performance of the treatment planning systems. The idea behind is to show the possibility to adapt the CNAO standard beam line, with some optimization, for dose delivery to the human eye without any dramatic change of the present machine experimental setup. This study is also important as a prediction tool to implement new detectors (body organs, experimental water detectors), active/passive beam setup components and to evaluate the dose received on the target and its three dimensional geometrical distribution. Patient treatment plans are also studied and analyzed (Adele Rimoldi).

6.2 THEORETICAL AND MATHEMATICAL PHYSICS

6.2.1 Quantum Gravity and Quantum Field Theory

Among the many significant ideas and developments that connect Mathematics with contemporary Physics one of the most intriguing is the role that Quantum Field Theory (QFT) plays in Geometry and Topology. We can argue back and forth on the relevance of such a role, but the perspective QFT offers is often surprising and far reaching. Examples abound, and a fine selection is provided by the revealing insights offered by Yang–Mills theory into the topology of 4-manifolds, by the relation between Knot Theory and topological QFT, and most recently by the interaction between Strings, Riemann moduli space, and enumerative geometry. These techniques afford a geometrical perspective which is always quite non–trivial and extremely rich. It is within such a Quantum Geometry framework that our group (M. Carfora, A. Marzuoli, C. Dappiaggi) investigates aspects of the relation between an important class of QFTs, General Relativity, Cosmology, and Quantum Gravity. Specific research themes that we address and which offer a wide range of possibilities for PhD thesis are: Quantum Field Theory on curved spacetimes; Ricci flow and Quantum Field Theory Landscaping; Two-dimensional Quantum Gravity, String Dualities, and the geometry of Riemann Moduli Space theory; Topology of manifolds and Topological Quantum Field Theory; Combinatorial Framework for Topological Quantum Computing. (Mauro Carfora)

6.2.2 Hadronic structure and QCD: theory and phenomenology

Our goal is to explore and understand the internal structure of nucleons in terms of their elementary constituents, i.e., quarks and gluons. Our research activity aims at answering fundamental questions such as: Can we define a ”shape” of the nucleon and how does it look like? What generates the spin of the nucleon? In principle, the structure of the nucleon should be computed starting from the theory of Quantum Chromodynamics (QCD). In practice, the confinement of quarks and gluons within nucleons is a nonperturbative phenomenon, and QCD is extremely hard to solve in nonperturbative regimes. For this reason, despite the enormous progress of the last decades, we still have a limited knowledge of the internal structure of nucleons, which constitute more than $99_0/^0$ of ordinary matter. We turn to experimental measurements to gather the largest amount of information concerning nucleon structure. We make use of the tools of perturbative QCD to study hard scattering processes such as Deep Inelastic Scattering. We try to interpret the experimental measurements in terms of quark and gluon distribution functions. We compute the relevant quantities using models that effectively replace nonperturbative QCD. We make predictions for unmeasured observables. We actively participate in suggesting and planning future experimental measurements. Specific research themes that our group (A. Bacchetta, M. Guagnelli, B. Pasquini, M. Radici) addresses and that offer a wide range of possibilities for PhD thesis are: phenomenological and formal studies of transverse-momentum dependent parton distributions and generalized parton distributions; modeling parton distributions; study of the spin structure of the proton. (A. Bacchetta, M. Guagnelli, B. Pasquini, M. Radici)

6.2.3 Nuclear theory: electroweak reactions and stable and exotic nuclei

In spite of many decades of successful studies, the structure of nuclei is not yet completely understood. Sophisticated mean field theories have produced a wealth of data, but have also shown up their limits. The role of correlations in nuclei is larger than expected. The short range correlations, which are due to the short-range repulsion of the nucleon-nucleon interaction, have been deeply investigated, thanks to the use of realistic forces including many-body contributions, but it was found that large effects are also given by tensor correlations, which are due to the tensor component of the nuclear interaction, and to long-range correlations, which are due to the coupling between the single-particle dynamics and the collective excitation modes of the nucleus. Electron scattering reactions appear a preferential tool to investigate nuclear properties, in particular, but not only, single-particle ones. Inclusive and exclusive quasi-elastic electron scattering and electron-induced reactions with direct one- and two-nucleon emission have been widely investigated in Pavia. Neutrino interactions can be used in a similar way and, notwithstanding their very small cross sections, have the advantage of being sensitive to parity non conserving components of the nuclear current. Moreover, neutrinos are important for astrophysical studies, as their small interaction makes it possible to investigate the inner properties of stars. As their detection implies finite nuclei, it is essential to know with high precision the mechanism of their interaction with nuclei and the related cross sections. Exotic nuclei, which are nuclei with neutron or proton excess, are also important in astrophysics, as they can have a sensible effect in the process of nucleosynthesis. Moreover, they can give insight into the evolution of nuclear properties when the neutron-proton asymmetry increases. New phenomena are expected, in particular with respect to the shell model.

Our group (C. Giusti, F.D. Pacati, A. Meucci) has been involved for many years in collaborations with international laboratories to explain the experimental data and to predict the order of magnitude of the quantities to be measured in new experiments. We are also actively involved in national and international collaborations with theoretical groups for the comparison of different models and the development of new and more refined models for the analysis of data from electron and neutrino scattering experiments.

Specific research themes that our group addresses and that offer a wide range of possibilities for PhD theses: nuclear reactions with electroweak probes, relativistic models for quasi-elastic electron and neutrino-nucleus scattering, electron-induced reactions on exotic nuclei, relativistic mean field models. (C. Giusti)

6.2.4 Theoretical physics of elementary particles

With the announcement of the observation of a Higgs-like particle at the CERN LHC, particle physics entered a new era. The next endeavour demands to probe the fundamental properties of the newly discovered boson, such as its spin and parity, its couplings to the different fermions and gauge bosons and its self-coupling. It will be also important to establish whether the newly found boson is a fundamental or a composite particle, and whether this discovery is just the coronation of the Standard Model or a milestone along a path yet largely unexplored. To this end, it will be crucial to pursue the search for new particles beyond the spectrum of the Standard Model in the next years to come, as well as to perform precision measurements of the production processes and decays of the Higgs-like particle. This research is expected to take place at the energy and intensity frontiers and is strictly tight to the cosmic frontier, since from collider experiments it will be possible to infer the existence - and possibly to discover candidate particles able to solve the problem of the origin of the dark matter in the universe. The activity of the high energy theory group falls in the above general framework.

The team (G. Montagna, O. Nicrosini and F. Piccinini) has been actively involved for many years in the development of precision calculations and Monte Carlo generators for physics studies at the colliders at energy and intensity frontiers.

Theoretical research is carried out in view of the analysis of real collider data, both at the hadron colliders Tevatron and LHC and at electron-positron colliders at the GeV scale (flavor factories). Specific research themes that are currently addressed and offer a wide range of possibilities for a PhD thesis are: electroweak and QCD physics at the LHC, study of the properties of the Higgs boson and nature of the mechanism of electroweak symmetry breaking, higher-order calculations for tests of the Standard Model and searches for new physics at hadron colliders and flavor factories (G. Montagna, O. Nicrosini and F. Piccinini).

6.3 CONDENSED MATTER, OPTICAL PHYSICS, QUANTUM INFORMATION

6.3.1 PHOTONICS AND NANOSTRUCTURES

The Photonics and Nanostructures research group evolves from solid state physics and optical properties of materials, to recent advances in optical investigations of materials with micrometric and sub-micrometric structures the area that is broadly called nanophotonics and plasmonics. The Optical Spectroscopy Laboratory is equipped with a number of different techniques on a broad spectral range (from far infrared to vacuum ultraviolet): beyond the most common experiments based on reflectance, absorbance, photoluminescence, ellipsometry, dedicated set-ups have been implemented, both spatially and temporally resolved, to perform linear and nonlinear photonics and plasmonics studies (G. Guizzetti, F. Marabelli, M. Patrini, M. Galli, D. Bajoni). Theoretical research is developed both in support to experimental activities, and for basic investigations of radiation-matter interaction and nanophotonic systems (L.C. Andreani, D. Gerace, M. Liscidini, see also Quantum Photonics section). The group activities are presently focussed on three main research topics:

a. The electronic structure and the optical response of semiconductors, especially III-V compounds, Silicon, and metals, in bulk materials and heterostructures, as thin films, wires, dots. More recently, an activity on polymeric and conjugate polymeric semiconductors has started, with emphasis on optical response and photophysics of excited states. Applications of these materials (both semiconductors and polymers) are especially in the fields of microelectronics, optoelectronics, and photovoltaics beyond other material-science issues.

b. The experimental investigation of photonic crystals, i.e. systems with a periodic dielectric function in one, two, or three dimensions. Such systems are particularly interesting for a great variety of physical phenomena and they are promising for applications to optoelectronics and optical communication, lasers, integrated photonics and photovoltaic energy conversion. The investigated structures include photonic crystal waveguides and nanocavities in Silicon, SOI and III-V semiconductors for the control of light propagation, enhanced light emission, and quantum photonics experiments, but also 3D structures like direct and inverse opals.

c. Plasmonic or hybrid photonic systems, with applications in the development of photonic biosensors, and plasmonic surfaces for chemical and biochemical interactions. Two different systems have been proposed: i) dielectric multilayers supporting Bloch surface waves; ii) metallic nanostructures supporting surface plasmons polaritons, both propagating and localized. In both cases the e.m. field confinement and amplification allow the detection at high sensitivity in the far-field of biomolecular species chemically bound or adsorbed on the active area of the biosensor. Optical detection is feasible via surface Plasmon resonances (SPR), fluorescence, surface Raman scattering, or light diffraction signals. (M. Patrini)

6.3.2 QUANTUM PHOTONICS

From the theoretical side, the group of Photonics and Nanostructures has been dealing with a number of problems related to the optical properties, and radiation-matter interaction effects in complex photonic and plasmonic nanostructures, such as photonic crystals, waveguides, nanocavities (L.C. Andreani, D. Gerace, M. Liscidini).

Semiclassical and quantum descriptions of radiation-matter interaction are also a subject of considerable interest within the group. Here the concept of photon confinement in low-dimensional dielectric lattices is linked to the analogous concept of electron confinement in semiconductor nanostructures. Our current activities are still focused on theoretical descriptions photonic and electronic nanostructures, with the aid of models as well as various numerical approaches. For more information, please visit the link to the webpage nanophotonics.

Quantum photonics is an emerging field of nanoscale nonlinear optics, with the aim of studying and exploiting nonlinear optical properties in the extreme quantum limit, ultimately down to the single-photon level. We are interested in single-photon nonlinear optics in photonic nanostructures. Our interest is currently twofold: on one hand we are investigating the fundamental aspects of strongly correlated photonic systems, where the similarities of strongly coupled nonlinear cavities with strongly correlated electronic systems is a constant source of inspiration for the emergence of new physical phenomena; on the other, controlling single photons with single photons might provide prospective nanoscale devices, such as single-photon transistors or switches (D. Gerace)

6.3.3 Quantum Information and QFT

The Group QUIT (Quantum Information Theory Group) has worked in the field of Quantum information since the very beginning of the discipline, with main focus on designing new quantum measurements and transformations. QUIT pioneered the technique of quantum tomography of states and transformations, introduced the new notion of ”quantum comb” for optimizing quantum algorithms and quantum protocols, studied security of quantum cryptographic protocols, found numerous new types of optimal measurements and transformations. In the last ten years QUIT members used their experience in addressing foundations of quantum theory (QT), and, more recently, of quantum field theory (QFT). In 2011 A long PRA has been published where three authors of QUIT derived QT from six information theoretical axioms, work that got a viewpoint on Physics, and has been the object of sessions of international conferences. The new axiomatization lead to a new powerful diagrammatic framework for deriving general theorems, without using the mathematical representation of QT. Other groups internationally are currently involved in the new axiomatization program pioneered by QUIT, and the program has lead to new possibilities of proving statements about causality, nonlocality, hidden-variable representations, completeness, complementarity and similar issues for general probabilistic theories. This new angle for looking at QT ”from outside” is leading to new powerful insights about the structure and the epistemological motivation of QT.

In the last two years the information-theoretic program entered the real of QFT, leading to a quantum cellular automata (QCA) extension of QFT. The quantum automaton is the minimal-assumption extension to the Planck and ultra-relativistic scales of QFT. The QCA can describe localized states and measurements that are unmanageable by QFT. Without requirement of relativistic covariance and on the basis of simple general information theoretic postulates, (as the homogeneity of interactions and the quantum Church-Turing postulate), a unique minimal automaton is derivable in d=3 space-dimensions that recovers exactly the Dirac dynamics for low momenta and small mass, but provides also a unified description for the Planck scale. It leads to powerful predictions, e.g. a bound on the inertial mass, without using GR (e.g. based on arguments as mini-black holes). The automaton theory looks as a very promising framework for quantum gravity, since it is quantum ab-initio, with relativistic covariance as emergent and not assumed a priori, it is free from all the problems arising from continuum, it doesnt suffer violations of causality, and has no divergences. It is the natural scenario to accommodate the quantum holographic principle. Lorentz covariance and all other symmetries are violated in the ultrarelativistic Planckian regime, and are perfectly recovered at the Fermi-scale, making the QCA the perfect testing scenario for symmetry and Lorentz violations. (Giacomo Mauro D'Ariano)

6.3.4 Quantum Mechanics: quantum technologies and foundational problems

Quantum mechanics can be seen as a useful tool to achieve practical goals such as computation, communication, and precise measurements. These are all aspects of the fledgling field of quantum technology. In stark contrast, from the foundational point of view, quantum mechanics has some obvious gaps that mostly stem from its counter-intuitive nature.

Research in this field deals with both these aspects. Regarding quantum technologies, the main emphasis and results stem from quantum metrology. It studies how quantum effects (e.g. entanglement and squeezing) can be useful to increase the precision of measurements and to achieve the ultimate bounds on precision that quantum mechanics imposes (e.g. from the Heisenberg uncertainty relations). In quantum metrology we study protocols for specific types of measurements (e.g. position measurements, imaging, interferometry, etc.), but also the general theory of quantum metrology. Another important quantum technology aspect refers to quantum communication: communication requires information carriers that are physical systems. Quantum mechanics imposes limits to the amount of information they can carry through a communication channel. A still outstanding problem is the extension of Shannon's information theory to the quantum domain. Important results have been found that refer to the communication of information through optical and radio communication channels. Finally, still in the context of quantum technologies, many different quantum devices and protocols have been developed. For example, we developed and analyzed the quantum random access memory (QRAM), a fundamental component of future quantum computers. Another useful tool in the quantum toolbox stems from the unconditionally secure cryptography that quantum mechanics allows: cryptographic communication schemes that cannot be intercepted (without violating the laws of physics). Different quantum cryptographic protocols have been developed, for example for the cryptographically secure query of a database or for cryptographically secure computation.

Regarding the foundational aspects, we investigate some of the most problematic aspects of quantum mechanics, such as the origin of quantum probabilities, the quantum origin of the arrow of time, and the emergence of a quantum spacetime. These are all explored in the context of the quantum theory of measurement, that is a unifying trait for all these researches.

In conclusion, our research spans from practical schemes that constitute an indispensable toolkit for the approaching quantum technology era up to the investigation of some of the deepest mysteries in the foundations of modern quantum mechanics. (L. Maccone)

6.3.5 Magnetic Resonances in Condensed Matter

The research activity of the NMR group is focused on the study of the microscopic physical properties of matter by combining local probes techniques, as nuclear magnetic resonance (NMR) and muon spin resonance (SR), with techniques of macroscopic character as the SQUID magnetometry or the adiabatic calorimetry. The group is presently addressing three main research topics: a) *superconducting materials*; b) *low-dimensional and molecular magnetism*; c) *biomedical applications*.

a) The work in progress on the iron-based and high temperature superconductors aims at understanding the microscopic mechanisms involved in the Cooper pair formation. By means of NMR and SR spectra and relaxation rates measurements, the symmetry and amplitude of the superconducting order parameter is investigated as a function of different external parameters as the temperature, the magnetic field intensity, the pressure and the charge doping. These measurements allow also to study the modifications in the low-energy excitations in the normal state and to investigate the nanoscopic coexistence of the magnetic and superconducting ground-states which characterizes these materials The group is also involved in the study of the flux lines lattice motions in the mixed-state, a problem which is of significant interest both for the future technological applications of the superconductors and for the fundamental aspects involved.

b) The NMR group has a well established activity on the molecular magnets, which have attracted remarkable attention in recent years owing to their possible application as logic units. The aim is to study by means of magnetic resonance techniques the changes in the local spin configuration and in the low-frequency dynamics upon varying the number of spins from even to odd, their magnitude or the local crystal field and to investigate the formation of entangled spin-states. Part of the research activity on low-dimensional magnets is centred on the study of novel exotic ground-states which arise in frustrated magnetic systems, as the spin nematic, spin-ice and spin-liquid ones, or in intermetallic compounds.

c) The research activity in the biomedical area involves, first of all, the development of novel techniques and of materials which allow to improve the performance of Magnetic Resonance Imaging (MRI) diagnosis. In the last years the group has been involved in the development of the dynamical nuclear polarization technique which allows to open a new route towards in vivo molecular imaging of the metabolic processes. Moreover the group is studying functionalized magnetic nanoparticles which can be used either as MRI contrast agents, or for the drug delivery or, eventually, for the therapy of certain pathologies through hyperthermia. The group collaborates also in the development of the Boron Neutron Capture Therapy (BNCT) technique by studying the possibility to map the boron distribution prior to neutron irradiation. (Pietro Carretta)