UNIVERSITY
OF TRENTO - Italy
Department of Physics
Doctoral Programme in Physics

Academic year 2015/2016

SYLLABUS

(ANNEX TO THE TRAINING PROGRAMME)

Each PhD student must attend courses corresponding to 12 credits by choosing advanced courses organized:

- by the Doctoral Programme in Physics
- by the Master degree in Physics, or by other similar Master degree courses
- by other similar Doctoral programmes

Other mandatory activities include:

- Research activity followed by a tutor assigned by the Doctoral Programme Committee.
- Attendance of seminars organised by his/her own Research group
- Attendance of Dialogues, Colloquia and Joint Colloquia organized by the Department of Physics also on topics different from the research activity carried out by the PhD students.

Each student must submit his/her study plan to the Doctoral Programme Committee for the approval. The study plan must be previously agreed with the tutor.

The credits should be achieved within the end of the first year with the extension to the first semester of the second year only for Master degree courses activated in that time (for up to 6 credits).

PhD students can obtain up to 3 credits for the attendance of International Schools (Summer/ Winter school, etc.) upon the authorization by the tutor and the Doctoral Programme Committee and after passing an exam.

List of courses organized by the Doctoral Programme in Physics a.y. 2015/2016

Docente	Corso	Crediti	Ore
I. LAZZIZZERA	**ADVANCED COURSE ON FUNDAMENTAL INTERACTIONS**	3	21
G.A. PRODI, R.S. BRUSA (COORDINATORI)	**ADVANCED TECHNIQUES IN EXPERIMENTAL PHYSICS**	3	21
P. FORNASINI	**APPLICATIONS OF SYNCHROTRON RADIATION**	3	21
R. CIOLFI	**MULTIMESSENGER ASTROPHYSICS**	3	24
M. FERRARI	**OPTICAL AND SPECTROSCOPIC DIAGNOSTIC OF MATERIALS FOR PHOTONICS**	3	21
M. CERDONIO	**SPACE-TIME AND GRAVITATION: AN EXPERIMENTALIST OVERVIEW**	3	21
TALENT (Training in Advanced Low-Energy Nuclear Physics)	**(TITLE NOT YET AVAILABLE)**	6	45
ECT* (European Centre for theoretical Studies in Nuclear Physics and related Areas)	**ECT* DOCTORAL TRAINING PROGRAMME 2016**	*	
SISSA (Scuola Internazionale Superiore di Studi Avanzati)	**(COURSES TO BE DEFINED)**	**	
CIAL	**CORSO DI INGLESE TECNICO – LIVELLO B2**	***	24

*up to 6 credits
**up to 6 credits
***up to 3 credits in addition to the 12 mandatory credits.

ADVANCED COURSE ON FUNDAMENTAL INTERACTIONS, PROF. I. LAZZIZZERA

Prerequisites

Prerequisites are knowledge of fundamentals in Electroweak and Hadron Physics, as well as in Relativistic Quantum Field Theories.

Contents

Programme

- General features of the Standard Model. Z and W production and decays.
- The search for the higgs particle: day update from the LHC.
- CP violation: Physics at the LHC and SuperB.
- Supersymmetries and Dark Matter candidates: update from the LHC.

Schedule

Schedule: to be agreed with interested students;

Exam

A short presentation on an argument the student wants to choose

Bibliography

Lecture notes will be available.

ADVANCED TECHNIQUES IN EXPERIMENTAL PHYSICS, PROFF. R.S: BRUSA E G. A. PRODI

Prerequisites

The knowledge of a physics graduate is requested.

Contents

This course is organized as a collection of 4-5 lecture cycles on different topics in advanced experimental physics. Each cycle is given by an invited scientist and consists in about 5-6 hours of lectures. The topics are selected every year in experimental research areas of interest of the physics department, giving priority to topics not already discussed in other dedicated PhD courses, as for instance:

1) Antimatter experiments, anti-hydrogen, positron beams, use of positronium in material studies;
2) Applications of particle beams in medicine;
3) Biophysics, in particular methods for the conditioning/investigation of single biological molecules and for the imaging;
4) Cold gases condensates, atomic interferometry;
5) Fundamental noise limits in motion detectors, standard quantum noise limit, ;
6) Instrumentation and methods for observational astrophysics and cosmology;
7) Instrumentation and methods in condensed matter and glasses and in surface science;
8) Particle and radiation detectors;
9) High energy Physics;
10) Photonic devices;

The selection of topics of the course depends also on the availability of lecturers from coming from other research institutes. The schedule of the course has to match the agenda of the lecturers and it is provisionally planned.

Schedule

Period: **between December 2015 and June 2016**
Further information:
brusa@science.unitn.it; giovanniandrea.prodi@unitn.it

Exam

PhD students will give a seminar

Bibliography

APPLICATIONS OF SYNCHROTRON RADIATION, PROF. PAOLO FORNASINI

Important note: If the course "Interaction of X Radiation with Matter", proposed for the 2nd level degree in Physics (laurea magistrale), is activated in the second semester, the interested PhD students are asked to take this course, or part of it, in substitution of "Synchrotron Radiation and its applications".

Prerequisites

Prerequisites: basics of special relativity and classical electrodynamics, time-dependent perturbation theory.

Contents

The course aims at a phenomenological review of synchrotron radiation properties, generation and some of the main applications.

Preliminary contents
1 - General introduction to Synchrotron Radiation
Emission of electromagnetic radiation from accelerating charges, the relativistic case
Main properties of synchrotron radiation: angular distribution, spectral distribution, time structure, polarization
2. - Synchrotron Radiation generation and use
Storage rings, structure and operation - Bending magnets and insertion devices: wigglers, undulators, free-electron lasers - Beamlines and their optical components
3 - Overview of the main techniques utilizing Synchrotron Radiation
Properties of X-rays - Absorption and photoemission spectroscopy - Elastic and inelastic scattering - Imaging
4 - Elastic scattering - Diffraction
Basics of X-ray scattering, resonant scattering - Wide angle scattering from crystalline and non-crystalline samples, temperature effects - Small angle scattering - Comparison with elastic neutron and electron scattering
5 - Absorption spectroscopy - EXAFS
Basic principles of photoionisation - Theory of EXAFS - Experimental apparatuses and data analysis procedures - Main applications of EXAFS
6 - Inelastic scattering [the lectures will be given by prof. Giulio Monaco]
Cross-section for non-resonant inelastic scattering - The dynamic structure factor – Optical components required for an inelastic scattering experiment – Examples of experimental results obtained in crystalline and disordered materials

Schedule

The lectures will be given from February to May 2016 (two hours per week).

Exam

The final exam consists in a seminar (approximately 30-40 minutes) on a subject, chosen by the student, connected to synchrotron radiation and its applications: the subject can directly pertain to his research interests or can be a review of some recent research papers.

One or more days (depending on the number of students) will be dedicated to the seminars, no later than the end of June.

References

The slides will be at disposal of students.
References on specific subjects will be suggested during the course.

Bibliography

References.
The slides will be at disposal of students.
References on specific subjects will be suggested during the course.

MULTIMESSENGER ASTROPHYSICS – DOTT. RICCARDO CIOLFI

Prerequisites

Typical competencies of Physics graduate students, in particular Special Relativity (General Relativity, although beneficial, is not a mandatory prerequisite).

Contents

Supernova explosions and gamma-ray bursts are among the most energetic phenomena observed in our Universe. They are associated with the formation of compact objects such as neutron stars and black holes and, as such, they represent unique laboratories to study physics under extreme conditions. The course will provide an up-to-date overview of these events from both a theoretical and an observational perspective, covering the different and complementary emission channels that characterize them: electromagnetic radiation, neutrinos and gravitational waves.

Lectures will cover the following topics:
1. Stellar evolution and compact object formation. Supernovae (SNe) and compact binaries as formation channels. Properties of compact objects (overview).
2. Introduction to SNe: 1987A. SN observations, different SN types/progenitors. Role of SNe in cosmology and high-energy astrophysics.
3. Core-collapse SNe (CCSNe): observations. CCSN dynamics I (latest results from numerical simulations)
4. CCSN dynamics II (continuation). Radiation, nuclosynthesis, r-process, kilonovae.
5. Neutrinos from SNe.
6. Gravitational waves (GWs): theoretical introduction. The challenge of GW detection (overview on ground and space-based detectors). GW from CCSNe.
7. SN summary: SNe in a multimessenger perspective. Gamma-ray bursts (GRBs): introduction (long-short divide, observations, overview of progenitors).

8. Relativistic jets.
9. Long GRB modelling from first observations to present.
10. Short GRBs (SGRBs): binary progenitors. Dynamics I: "standard" black hole-torus picture, BZ vs MHD mechanism. Radiation, nuclosynthesis and neutrinos.
11. SGRB Dynamics II: X-ray afterglows and magnetar model. Time-reversal scenario. Radiation, nuclosynthesis and neutrinos in the magnetar case.
12. SGRB Dynamics III: GWs from compact binaries. Electromagnetic counterparts. Advanced detectors at work: data analysis pipelines. Prospects for SGRB/GW coincident detection.

Schedule

Lectures will be given from November 2015 to February 2016 (2-hour lectures, generally once per week).

Exam

The final exam will consist of a 30-40 minutes seminar on a subject closely related to the course. Typical seminars are based on a highly relevant paper chosen by the student (possibly, but not necessarily, from a list of suggestions that will be provided).

Bibliography

A number of selected review papers and the following books (all available in the UNITN library):
D. Arnett - Supernovae and nucleosynthesis M.S. Longair - High-energy astrophysics
S.L. Shapiro, S.A. Teukolsky - Black Holes, White Dwarfs and Neutron Stars: The Physics of Compact Objects
S. Rosswog, M. Brueggen – Introduction to High-Energy Astrophysics
F. Melia – High-Energy Astrophysics
B. Schutz – A First Course in General Relativity (complementary)

OPTICAL AND SPECTROSCOPIC DIAGNOSTIC OF MATERIALS FOR PHOTONICS, DR. MAURIZIO FERRARI

Prerequisites

The typical skills of a Physics graduate are requested.

Contents

Phenomenological course

Programme

- Introduction to Glass Photonics

- From bulk to nano- and microscale photonics systems
- Rare earth – activated glasses
- Photonics devices fabrication and assessment
- Radiative and non-radiative transitions
- Transition probability
- Energy transfer
- Absorption and emission cross sections; Quantum efficiency
- Light scattering for characterization of material properties
- Confined structures: Planar waveguides
- Confined structures: Nanospheres
- Confined structures: Direct and inverse opals
- Confined structures: Spherical Microresonators
- Confined structures: 1D - Microcavities
- Nanocomposites systems and transparent glass ceramics
- Energy conversion
- Plasmonic structures
- SERS
- Fluorescence enhancement using different sensitizers – metallic and semiconductor nanoparticles, lanthanides ions, nanocrystals.
- Solar energy conversion by quantum cutting.

Schedule

From November 2015

Exam

Seminar and discussion

Bibliography

specific papers and books will be suggested during the lectures

Space-Time and Gravitation: an experimentalist overview, Prof. Massimo Cerdonio

Prerequisites

Basic courses in Physics and in Mathematical Methods

Contents

The course will present and discuss past, recent and contemporary experiments and observations in the physics of space-time and gravitation on Earth and its vicinities and in the Cosmos. The initial focus will be to introduce special and general relativity from an experimentalist view, by discussing classic tests and experiments, both in the original and in the recent high tech realizations. Then it will be discussed on one hand the impact of the forthcoming gravitational wave astronomy on fundamental physics and cosmology, and on the other hand the chances of precision experiments to explore the realm of the Planck regime. The balance between the two parts of the course will be modulated according to the interests and desires of the students.

From space & time to space-time.
• Inertial observers, light and clocks: light speed experiments and realization of inertial frames with clocks and light signals
• Length contraction from a simple exp in electrostatics: Lorentz transformations; relativity of simultaneity; time dilation and the “twins”; Doppler effect; Cerenkov effect.
• Mass and energy: $E=mc^2$; experiments with photon absorption and emission, Compton effect, particle colliders
• Accelerated motion (linear): constant acceleration, “event horizon”, limits to interstellar travel, the accelerated "twins"
• Accelerated motion (rotation): Foucault pendulum, Sagnac effect and gyrolasers, gyromagnetic effects of Barnett and Einstein-DeHaas, Thomas precession.

From the Equivalence Principle to gravity curving space-time.
• Uniqueness of paths in gravitational fields: inertial mass and gravitational mass, esperiments from Galileo and Newton to Eotvos and Roll-Krotkov-Dicke and Adelberger; the Equivalence Principle, EP
• Limits on contributions from different fundamental interactions; Moon telemetry and the Nordvedt effect; experimental limits on EP
• Local inertial frames; “drag free” satellites
•EP and clocks in gravitational fields: gravitational “red-shift”; experiments by Leschiutta, Pound&Rebka, Hafele&Keating, Alley and by Vessot& Levine; the Global Positioning System, GPS
• Gravity affects standard clocks in a flat space-time vs. gravity curves space-time. Heuristic construction of metrics of curved space-time as small perturbation to Minkowski metrics: uniform rotation, weak gravitational field
• Post-Newtonian Parameterization (PPN): parameters α, β, γ for experimental tests on alternative theories

Space-time and gravitation
• The metric outside a central non-rotating mass: the Schwarzschild metric; Newtonian limit; space curvature contribution to post-Newtonian metric
• Coordinates and measurements: radar distance, parallax, etc; gravitational red shift; escape velocity
• Orbits of test particles and of photons: first integral of eq of motion, symmetries and conservations
• The Schwarszchild radius: far from, close to, crossing it; black-holes
• The “classical” tests of General Relativity within PPN: α, β, γ and limits on alternative theories; perihelium of Mercury; light deflection and the Shapiro delay in the solar system
• Orbiting gyroscopes: the DeSitter precession
• Linearized relativistic gravitation “Maxwell-like”: “gravitomagnetism” and “gravitational waves”; Schiff precession and Lense-Thirring dragging of inertial frames: recent measurements with GP-B and

LAGEOS; gravitational lensing and searches for dark objects – planets, small black-holes, etc ; evidence for emission of gravitational waves: the Hulse & Taylor binary pulsar, the double pulsar binaries.

Experiments and observations in relativistic gravitation
To be given in the second part of the course > not enough time for all the matters listed below > will choose subject(s) with the students
•Towards a new "gravitational wave astronomy" before 2020: coalescing and merging black-hole and neutron star binaries versus detection capabilities of earth and space interferometers: LIGO/Virgo/KAGRA/GEO-HF and LISA
• Fundamentals of GR, cosmography and cosmology with gw observations: GR in the strong field regime; "black" supermassive objects in the galactic nuclei as the Kerr black holes of GR; black holes "thermodynamics"; black hole binaries as "standard sirens" to get "unaided" the Hubble constant and the dark energy equation of state; black holes and cosmic evolution; the impact on cosmology of the observation of a gw cosmological background
• Beyond GR and QM: the quest for experiments on a "minimal length" and on "generalized uncertainty principle"

Schedule

Available to start early December for 3/5 of the course before Christmas; would lecture in the morning of two consecutive days (no preference which, within the week)
Contact for further info: cerdonio@pd.infn.it

Exam

In two parts: *first* the student will give, before the end of the lectures, a 20' presentation on a specific topic related to the course, and, *second*, will give an oral exam on other parts of the course in a session to be held not later than few weeks after the end of the lectures

Bibliography

Books
"Introduction to relativity" J.B.Kogut (Harcourt/Academic Press 2001)
"Special relativity" A.P.French (Chapman & Hall 1991)
"Gravity" James.B.Hartle (Addison Wesley 2003)
"Relativity Special, General and Cosmological" W.Rindler (II edition Oxford Univ. Press 2006)
"General Relativity" M.P.Hobson, G.Efstathiou and A.N.Lasenby (Cambridge 2006)

References
"The Confrontation between General Relativity and Experiment" C. M. Will, Living Reviews in Relativity **9** (2006) http://relativity.livingreviews.org/
"Gravitational waves: from discovery to astronomy" M. Cerdonio and G. Losurdo, La Rivista del Nuovo Cimento **35** (2012)389.

A number of papers on various aspects as paradoxes, more detailed/simplified calculations, historical matters, etc from major journals as Am.J.Phys., Gen. Rel. Gravitation, Class. Quantum Grav., and from the arXiv will distributed to the students, according to their interest and demands.

TALENT 2016

Programme not yet available http://www.ectstar.eu/

ECT* Doctoral Training Programme 2016

Programme not yet available http://www.ectstar.eu/

SISSA

Courses of the Master degree in Physics (http://web.unitn.it/en/dphys/6763/calendar-and-timetable)
Starting in the second semester of the a.y. 2015/2016.

Technical and scientific English (Level B2)

Prerequisites

Entry level: B1b

Schedule

Presumably in January 2016 – intensive course (with at least 10 students).