Academic year 2017/2018

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. 2017/2018

Professor	Course	Credits	Hours
G.A. Prodi, R.S. Brusa (coordinatori)	**Advanced Techniques in Experimental Physics**	3	21
M. Dapor	**Computational Methods for Transport Phenomena**	3	21
M. Ferrari	**Optical and Spectroscopic Diagnostic of Materials for Photonics**	3	21
M. Cerdonio	**Space-Time and Gravitation: an experimentalist overview**	3	21
R. Iuppa, G. A. Prodi	**Fundamental interactions**	3	21
A. Perreca	**Advanced Interferometry**	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 2018**	*	
SISSA (Scuola Internazionale Superiore di Studi Avanzati)	**(Courses to be defined)**	**	

*up to 6 credits
**up to 6 credits

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 lecture cycles on different topics in advanced experimental physics. Each cycle is given by an invited scientist or a member of the department, 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 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 2017 and June 2018**

Further information:

robertosennen.brusa@unitn.it; giovanniandrea.prodi@unitn.it

Exam

PhD students will give a seminar of 20 minutes on an experimental topic related to the four lectures or to an experimental research presented in the Dialogues, Colloquia and Joint Colloquia. The topic is freely chosen by the PhD student but must be previously agreed with the coordinators of the course and must be different from the field of research of the PhD student.

Bibliography

To be defined.

COMPUTATIONAL METHODS FOR TRANSPORT PHENOMENA, DR. M. DAPOR

Prerequisites
Modern Physics

Contents
1. Cross-sections: basic aspects
    1.1 Cross-section and probability of scattering
    1.2 Stopping power and inelastic mean free path
    1.3 Range
    1.4 Energy straggling

2. Scattering mechanisms
    2.1 Elastic scattering
        2.1.1 Mott cross-section vs. screened Rutherford cross-section
    2.2 Quasi-elastic scattering
        2.2.1 Electron-phonon interaction
    2.3 Inelastic scattering
        2.3.1 Stopping: Bethe-Bloch formula
        2.3.2 Stopping: semi-empiric formulas
        2.3.3 Dielectric theory
        2.3.4 Sum of Drude functions
        2.3.5 Mermin theory
        2.3.6 Polaronic effect
    2.4 Inelastic Mean Free Path
    2.5 Surface phenomena

3. Random numbers
    3.1 Generating pseudo-random numbers
    3.2 Testing pseudo-random number generators
    3.3 Pseudo-random numbers distributed according to a given probability density
    3.4 Pseudo-random numbers uniformly distributed in the interval [a; b]
    3.5 Pseudo-random numbers distributed according to the Poisson density of probability
    3.6 Pseudo-random numbers distributed according to the Gauss density of probability

4. Monte Carlo strategies
    4.1 The continuous-slowing-down approximation
        4.1.1 The step-length
        4.1.2 Interface between over-layer and substrate
        4.1.3 The polar scattering angle
        4.1.4 Direction of the electron after the last deflection
        4.1.5 The energy loss

4.1.6 End of the trajectory and number of trajectories
4.2 The energy-straggling strategy
4.2.1 The step-length
4.2.2 Elastic and inelastic scattering
4.2.3 Electron-electron collisions: scattering angle
4.2.4 Electron-phonon collisions: scattering angle
4.2.5 Direction of the electron after the last deflection
4.2.6 Transmission coefficient
4.2.7 Inelastic scattering linkage to the distance from the surface
4.2.8 End of the trajectory and number of trajectories

5. Backscattering coefficient
5.1 Electrons backscattered from bulk targets
5.2 Electrons backscattered from one layer deposited on semi-infinite substrates
5.3 Electrons backscattered from two layers deposited on semi-infinite substrates
5.4 A comparative study of electron and positron backscattering coefficients and depth distributions

6. Secondary electron yield
6.1 Secondary electron emission
6.2 MC approaches to the study of SE emission
6.3 Specific MC methodologies for SE studies
6.3.1 Continuous-slowing-down approximation (CSDA scheme)
6.3.2 Energy-straggling (ES scheme)
6.4 Secondary electron yield

7. Electron energy distributions
7.1 Monte Carlo simulation of the spectrum
7.2 Plasmon losses and electron energy loss spectroscopy
7.3 Energy losses of Auger electrons
7.4 Elastic peak electron spectroscopy (EPES)
7.5 Secondary electron spectrum

8. Applications
8.1 Linewidth measurement in critical dimension SEM
8.1.1 Nanometrology and linewidth measurement in CD SEM
8.1.2 Lateral and depth distributions
8.1.3 Secondary electron yield as a function of the angle of incidence
8.1.4 Linescan of a silicon step
8.1.5 Linescan of PMMA lines on a silicon substrate
8.2 Application to energy selective scanning electron microscopy
8.2.1 Doping contrast
8.2.2 Energy selective scanning electron microscopy

8.3 Proton cancer therapy
- 8.3.1 Proton track simulation and Bragg peak
- 8.3.2 Damage in the biomolecules by dissociative electron attachment
- 8.3.3 Simulation of the electron transport and further generation
- 8.3.4 Radial distribution of the energy deposited in PMMA by secondary electrons generated by energetic proton beams

Schedule

From February 2018

Exam

Seminar

Bibliography

P. Sigmund, Particle Penetration and Radiation Effects, Springer, Berlin, 2008
R.F. Egerton, Electron Energy-Loss Spectroscopy in the Electron Microscope, Springer, Berlin 2011
M. Dapor, Electron-Beam Interactions with Solids, Springer, Berlin, 2003
M. Dapor, Transport of Energetic Electrons in Solids, Springer, Berlin, 2014

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

Prerequisites

The typical skills of a Physics, Engineering 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
- Optical parameters, dispersion curve
- 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
- Integrated optics
- Resonant florescence line narrowing and spectral hole burning
- Single ion emission
- Homogeneous and inhomogeneous emission and absorption band
- Energy conversion
- Energy trapping
- Plasmonic structures
- Fluorescence enhancement using different sensitizers – metallic and semiconductor nanoparticles, lanthanides ions, nanocrystals.
- Fibers and fiber lasers
- Nano -micro thermometers
- Solar energy conversion by quantum cutting.
- Lightning
- Persistent luminescence
- Scintillators

Schedule

From November 2017 to February 2018

Exam

Seminar and discussion

Bibliography

Specific papers and books will be suggested during the lectures

SPACE-TIME AND GRAVITATION: AN EXPERIMENTALIST OVERVIEW, PROF. M. 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 first part will be dedicated 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. The second part will deal with the impact of the forthcoming gravitational wave astronomy and of precision experiments/observations to the features of space-time in the cosmology of early Universe. 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; perihelion 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, and the "direct" detection of "chirps" from black-hole 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 November (the course could be completed 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 (a few between which students may choose according to style and level they prefer)

"Introduction to relativity" J.B.Kogut (Harcourt/Academic Press 2001)
"Special relativity" A.P.French (Chapman & Hall 1991)

"Gravity" J.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 Univ.Press 2006)
"Cosmology" S.Weinberg (Oxford Univ.Press 2008)

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 be distributed to the students, according to their interest and demands.

FUNDAMENTAL INTERACTIONS, DR R. IUPPA AND PROF. G.A. PRODI

Contents

Description

This course aims at describing frontier experiments on fundamental interactions, pointing out common and distinctive features of different fields of Physics. We will discuss the most important observational results of the last two decades in High Energy Physics, Flavor Physics, Astroparticle Physics and Search for Dark Matter, Neutrino Physics and Astrophysics, Gravitational Wave Astronomy and Cosmology. Lectures will be focused on experimental techniques, showing strength points and explaining intrinsic limits of sensitivity.

Organization

This is a lecture course in which topics are presented by the teacher.

Course objectives

- To provide PhD students with basic knowledge of modern experimental techniques applied in research fields different from theirs.
- To introduce PhD students to scientific methods and techniques widespread in particle and astroparticle Physics.
- To give PhD students a taste of what the hunt for Dark Matter currently.

Course topics

- Gravitational Wave Astronomy, compact binary stars populations, tests of General Relativity and consequences in cosmology.
- Standard Model and Beyond. The ΛCDM model.
- Detecting particles, how to.
- The problem of MASS. The electroweak sector. LEP, Tevatron and the LHC. The Higgs sector. Searches for New Physics.
- The problem of BARYOGENESIS. CP violation. CPT violation measurements. Cosmic antimatter asymmetry.
- The problem of DARK MATTER. Hypotheses. Spin-dependent/spin-independent. The WIMP miracle. Direct and indirect searches.
- The problem of NEUTRINOS. Neutrino mass. Neutrino oscillation. Neutrinoless double-beta decay. Astrophysical neutrinos.

Schedule

To be defined.

Exam

Grading plan
Written exam (quizzes): 25%
Short report on a topic agreed with the teacher: 25%

Oral exam: 40%
Attendance: 10%

Bibliography

Teacher notes will be made available on time.

ADVANCED INTERFEROMETRY, DR A. PERRECA

Prerequisites

The knowledge of physics at graduate level is requested.

Contents

The course will present advanced interferometric techniques for current and future experiments. Interferometry is an important investigative technique in the fields of astronomy, photonics, engineering metrology, optical metrology, plasma physics, biomolecular interactions, optometry and quantum mechanics. Several interferometers topology are widely used in science for the measurement of small displacements, refractive index changes and surface irregularities down to quantum limited sensitivity. This course will describe principles and effects of various interferometry topologies and example of applications.

The course is organized as follows:

Topology

- Plane waves and Gaussian beams. Michelson Interferometer: contrast, displacement sensitivity, shot noise. Fabry-Perot cavities: stability, resonance condition, finesse. The Pound-Drever-Hall technique for the locking of cavities. Other interferometer topologies: Sagnac interferometer, Mac-Zehnder interferometer: scheme and characteristics. More interferometric techniques: time delay interferometry, laser-ranging interferometry.

Advanced Interferometry for Gravitational Waves detectors

- Brief introduction to gravitational waves. Detection of gravitational waves. LIGO-Virgo interferometers at the time of their detections: Detection principle, Main noise contributions, Sensitivity curve. Future earth based GW detectors. Project for space based interferometers

More application of advanced interferometry

- Interferometry for the Gravity Recovery and Climate Experiment GRACE: introduction and working principle, current results. The next future: Grace follow-on.
- Interferometry for rotation measurements: the Sagnac effect. Application: ring-laser and gyro-lasers. Ring lasers for geodesy measurements. Ring lasers for general relativity measurements. The Lens-Thirring effect.

Improving the interferometer sensitivity

- Quantum nature of light. Coherent and squeezed states. Application of squeezed light in advanced interferometry: the case of GW interferometers.

Schedule

From January 2018

Exam

Seminar and discussion

Bibliography

Specific papers and books will be suggested during the lectures

TALENT 2018

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

ECT* Doctoral Training Programme 2018

Programme not yet available: http://www.ectstar.eu/node/195

SISSA

Courses of the Master degree in Physics (http://offertaformativa.unitn.it/it/lm/fisica/studiare-e-frequentare)
Starting in the second semester of the a.y. 2017/2018.