University of Torino
Graduate Program in Physics

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Course proposal (2018-19)

Title	**01- Introducing Susy**
Prof.	Igor Pesando, pesando@to.infn.it
CFU	5
Period	20 hrs November 12-19, 2018 (first part) Monday 12, 14:30-16:30 aula verde Wednesday 14, 14:30-16:30 sala fubini Monday 19, 14:30-16:30 sala fubini Spring 2019 (second part)
Prerequisites	
Programme	1) Chiral multiplet in 4D Coleman-Mandula theorem, R symmetry, susy action for chiral superfield, non renormalization theorem and holomorphy 2) Vector multiplet in 4D Wess-Zumino gauge, susy action for vector multiplet 3) Susy breaking O' raifeartaigh model, Fayet-Iliopoulos model, soft breaking 4) Basic of MSSM the action, unwanted symmetries 5) Sugra in D=4 6) Moduli space of the vacua and IR effective description
Note(s)	**Students who are willing to attend this course are **REQUESTED** to register by sending an email to Prof.** **Pesando (ipesando@to.infn.it)**

Title	**02-Introduction to large-N limit**
Prof.	Marco Panero, panero@to.infn.it
CFU	5
Period	20 hrs, March 25-April 5 2019

Prerequisites	
Programme	1 - Introduction 2 - The large-N limit in O(N) vector models 3 - QCD with many colors: The 't Hooft limit and its phenomenological implications 4 - The role of the large-N limit in the gauge/gravity correspondence: A brief summary
Note(s)	**Students who are willing to attend this course are **REQUESTED** to register by sending an email to Prof. Panero (panero@to.infn.it).**

Title	03-*Introduction to the Physics of the Quark-Gluon Plasma*
Prof.	Andrea Beraudo and Marzia Nardi
CFU	5, 20 hrs
Period	March 18-29, 2019, from Monday to Friday 11h-13h
Pre-requisites	The course is completely self-contained: no previous knowledge of the subject will be assumed. It is accessible to Ph.D. students both with a theoretical and an experimental background.
Programme	-Symmetries and Thermodynamics of QCD -Transport Theory -Relativistic Hydrodynamics -Phenomenology of heavy-ion Collisions
Note	**Students who are willing to attend this course are **REQUESTED** to register by sending an email to Prof. Beraudo (beraudo@to.infn.it) and Prof. Nardi (nardi@to.infn.it).**

Title	***04-Dark Matter and Neutrino physics***
Prof.	Carlo Giunti and Marco Taoso
CFU	5
Period	Neutrino Physics (C. Giunti): 6, 7, 8, 9, 10 May from 15:00 to 17:00 in Aula Fubini Dark Matter (M. Taoso): 16 May from 15:00 to 17:00 in Aula Castagnoli 17 May from 15:00 to 17:00 in Aula Fubini 20 May from 9:00 to 11:00 in Aula Verde 21-22 May from 15:00 to 17:00 in Aula Castagnoli

Pre-requisites	
Programme	Neutrino Physics (C. Giunti) - Theory of neutrino masses and mixing - Theory of neutrino oscillations - Overview of neutrino phenomenology - Neutrinos in cosmology Dark Matter (M. Taoso) - Evidences for dark matter - Production mechanisms in the Early Universe - Indirect ction: photons, charged cosmic-rays, neutrinos - Direct detection - Collider searches - Axion - Primordial black holes
Note	**Students who are willing to attend this course are **REQUESTED** to register by sending an email to Prof. Giunti (giunti@to.infn.it) .**

Title	05- *Standard Model Effective Field Theory and its applications in Flavour Physics*
Prof.	Martin Jung, martin.jung@unito.it
CFU	5
Period	June 2019
Prerequisites	
Programme	The fact that no states beyond the Standard Model (SM) ones have been found so far indicates a sizable energy gap between the electroweak scale and that of potential New Physics. In such a situation, it is possible to formulate an effective theory (EFT) in terms of the SM degrees of freedom, respecting the SM symmetries. The resulting EFT provides a model-independent framework in which all theories beyond the SM fulfilling its assumptions can be analyzed in. This course aims to give an introduction to SMEFT, explicitly treating its formulation, ntages and limitations. In the second part applications are discussed, focussing on the question what information can be extracted from observations at energies much lower than the electroweak scale.
Note(s)	**Students who are willing to attend this course are **REQUESTED** to register by sending an email to Prof. Jung (martin.jung@unito.it)**

Title	*06-Calorimetry in particle physics experiments*
Prof.	R. Arcidiacono, arcidiacono@to.infn.it
CFU	4
Period	Autumn 2019
Prerequisites	
Goals	
Programme	The physics of calorimetry Detector response, energy resolution and position measurement Calorimeter design principles Front-end and trigger readout electronics Electromagnetic calorimeters Hadronics calorimeters Calibration techniques Some examples
NOTES	Students who are willing to attend this course are **REQUESTED** to register by sending an email to Prof. Roberta Arcidiacono (arcidiac@to.infn.it)

Title	**07- Experimental techniques for neutron detection**
Prof.	Roberto Bedogni Roberto.Bedogni@lnf.infn.it
CFU	2
Period	8 hrs from October 19th , 2 hrs per lecture
Prerequisites	Basic background knowledge of particle interaction with matter and of detector working principles
Goal	The peculiarities of neutron fields and neutron detection will be presented, so that participants will ideally be able to choose the correct detection technique according to the properties of the neutron field. In addition, they will gain sufficient knowledge to choose the testing/calibration condition and infrastructure for a correct final use of a detector.
Programme	1 - ICRU85 system: Introduction and explanation of the 2011 ICRU-recommended quantities for Radiometry, Interaction and Dosimetry with examples (modelling in Monte Carlo codes). (19 October 2018 - 2h) 2 - Neutron Measuring Instruments Detectors, spectrometers, dosemeters. Impact of the design on the response function. Concepts of energy- and angle-response. Relevant examples (fluence-meter, rem-meter, moderator-based spectrometer) (15 November 2018, 14-16, Aula Wataghin) 3 -Calibration fundamentals

	Calibration procedures. Types of calibration fields. Differences between calibration field and workplace field. (16 November 2018 - 9-11-Sala Castagnoli) 4- Cases studies A realistic workplace where the performance of different neutron-measuring devices is studied against the properties of the field (energy-distribution, scattering conditions, presence of contaminant field components).(10-14 december)
Bibliography	Course material and proper references will be given by the lecturer throughout the course
Note(s)	Lessons are given in a open seminar format

Title	***08*-Data Analysis Techniques**
Prof.	Livio Bianchi
CFU	6
Period	tbd
Prerequisites	Basics on statistics and probability theory Basic programming skills in c/c++
Goals	
Programme	Reminder of basic probability theory Monte Carlo methods (basic) Statistical methods for: - Parameter estimation (confidence intervals) - Hypothesis testing (general, goodness-of-fit)
Bibliography	See last year's course webpage
Notes	Students who are willing to attend this course are **REQUESTED** to register by sending an email to Prof. L. Bianchi (Livio.Bianchi@cern.ch)

Title	**09-The hunt for physics Beyond the Standard Model**
Prof.	Cristina Botta, cristina.Botta@cern.ch
CFU	3
Period	May 20-31, 2019
Prerequisites	Possibly: basic knowledge of particle accelerators and detectors, basic experience in data acquisition and analysis (Prof. Amapane’s course) and statistical interpretation tools (Dr. Ortona’s course), basic knowledge of Higgs and SUSY physics.
Goals	The student will learn how different analyses strategies are being designed - especially at particles colliders - to search for signatures of New Physics.
Programme	Introduction: overview on the shortcomings of the SM, the needs of new physics, the experimental approach towards these open questions, and the status of current searches The

	design of multipurpose experiments like ATLAS and CMS at LHC From RAW data to Phyiscs Objects: reconstruction and identification, global event description, performance Analyses strategy design: complementarity of different approaches Direct searches: Introduction to the most popular BSM models and to the signatures they can induce in these detectors Indirect searches: Precision measurements, rares SM processes
Bibliography	-

Title	**10- Numerical simulation of silicon particle detectors**
Prof.	Marco Mandurrino (marco.mandurrino@to.infn.it)
CFU	4
Period	16 hrs from January 2019, 2 hrs per lecture (3 theoretical classes + 3 hands-on sessions + follow-up + final discussion)
Prerequisites	Basic background knowledge of solid-state physics, particle detectors and numerical methods. Basic programming skills
Goal	Students will be driven from book-like topics about silicon properties and silicon-based devices towards the issues and the potentialities of designing a real particle detector. This will be achieved through the analysis of some actual structures to be implemented in high-energy physics experiments and thanks to the use of a Technology Computer-Aided Design (TCAD) tool
Programme	1. A review of basic concepts about solid-state physics: from orbitals to the theory of bands; carriers statistics; the p-n junction and the most important diode equations 2. Overview of typical numerical techniques for the simulation of electronic devices: from the Boltzmann equation (BTE) to semiclassical transport models; the drift-diffusion framework; generation/recombination of charge carriers; processes and models beyond the semiclassical picture (tunneling, ...) 3. From the analitical description to numerical modeling: linearization and discretization of the drift-diffusion model; algorithms for solving ODE; basic concepts about convergence issues of iterative methods; introduction to the TCAD (Technology Computer-Aided Design) simulation approach 4. Description of the commercial tool Synopsys(C) Sentaurus Device 5. Hands-on sessions: 5a.) simulation of a simple 1D silicon diode; 5b.) 2D implementation of a pn-junction-based silicon

	sensor; 5c.) more advanced simulations of a realistic particle detector 6. Follow-up activities on the simulator concerning the final project 7. At the end of the course students will discuss with the lecturer and the class a project investigating the simulation of a device of their own choice (individual or in small groups)
Bibliography	Course material and proper references will be given by the lecturer throughout the course
Notes	Interested students are requested to register sending an email to Dr Mandurrino (marco.mandurrino@to.infn.it)

Title	***11- Cherenkov detectors for particle and astroparticle physics***
Prof.	U. Tamponi, tamponi@to.infn.it
CFU	4
Period	16 hrs, 17-18 April ; 6-10 May 2019
Prerequisites	
Programme	The course will have a first introduction about the general aspects of the Cherenkov effect, followed by an overview of its modern applications: particle identification at collider experiments, calorimetry, high energy cosmic rays detection and neutrino physics. Detailed program: - Theory of the Cherenkov effect (basics) - Foundamental particle identification techniques. - DIRC- and RICH-like detectors - Cherenkov effect in HEP calorimetry - Cherenkov-based telescopes for astroparticle and neutrino physics (Icecube, CTA...) - The Askaryan effect: neutrino detection and calorimetry applications At the end of the course the students will be required to give a seminar about a detector of their own choice, based on the Cherenkov effect.
NOTES	Students who are willing to attend this course are **REQUESTED** to register by sending an email to Dr. Umberto Tamponi (tamponi@to.infn.it)

Title	***12- Big Data Science and Machine Learning***
Prof.	F. Legger, federica.legger@to.infn.it
CFU	2
Period	8 hours (2h/lesson) + hands on (2h), 18-30 September 2019
Prerequisites	Basic knowledge of python
	Data science is one of the fastest growing fields of information technology, with wide applications in key sectors such as research, industry, public administration. The course will cover the definition of big data and the basic techniques to

Goal	store, handle and process them. Machine Learning (ML) and Deep Learning (DL) algorithms will be briefly introduced. We will focus on the technical implementation of different ML algorithms, focusing on the parallelisation aspects and the deployment on distributed resources and different architectures (CPUs, FPGAs, GPUs).
Programme	- Introduction to big data science - The big data pipeline: state-of-the-art tools and technologies - ML and DL methods: supervised and unsupervised training, neural network models - Parallelisation of ML algorithms on distributed resources - Beyond CPUs: ML applications on distributed architectures, GPUs, FPGAs
Bibliography	Chen, M., Mao, S. & Liu, Y. Mobile Netw Appl (2014) 19: 171. https://doi.org/10.1007/s11036-013-0489-0 Yao, Yuanshun & Xiao, Zhujun & Wang, Bolun & Viswanath, Bimal & Zheng, Haitao & Y. Zhao, Ben. (2017). Complexity vs. performance: empirical analysis of machine learning as a service. 384-397. 10.1145/3131365.3131372
NOTES	Students who are willing to attend this course are **REQUESTED** to register by email before August 2019 (federica.legger@to.infn.it)

Title	*13- Quantum communication*
Prof.	Prof. Ivo Degiovanni i.degiovanni@inrim.it
CFU	4
Period	16 hrs, h 14:30-17:30-Aula Avogadro June 25, July 1, 5, 12 , 15 (-->Aula Verde), 19, 22
Goals	The most peculiar characteristics of quantum mechanics are the existence of indivisible quanta and entangled systems. Both of these are the roots of Quantum Communication which could very well be the first engineered application of quantum physics at the individual quantum level. In particular Quantum cryptography has great potential to become the key technology for securing confidentiality and privacy of communication in the future ICT world. Here the fundamentals of quantum communication are introduced. Main applications with experimental implementations are presented. Experimental results and technological challenges are discussed.

Programme	a) Introduction to quantum information The qubit concept Qubit practical realisations No-cloning theorem Quantum state tomography b) Quantum Cryptography with single photons Quantum key distribution Experimental implementations Von Neumann Entropy vs. Shannon Entropy Eavesdropping strategy and security criteria c) Quantum entanglement Entangled states and their properties Practical realisations Bell's inequality d) Quantum Cryptography by entangled states Protocols Experimental implementations e) Quantum protocols Teleportation of qubits Teleportation of entanglement: entanglement swapping Quantum dense coding Experimental implementations of Bell's state analysis f) Generalized evolution of quantum systems Quantum operations Tomography of quantum operations
Bibliography	

Title	***14- Introduction to Turbulence***
Prof.	Filippo De Lillo,
CFU	3
Period	12 hrs, **starting on February 11**
Prerequisites	
Programme	The Navier-Stokes equations The phenomenology of fluid turbulence. Statistical description of turbulence A.N. Kolmogorov's 1941 theory. Intermittency and the multifractal formalism. Numerical simulations of the Navier-Stokes equations.
Bibliography	U. Frisch, "Turbulence: the legacy of A.N. Kolmogorov", Cambridge University Press (1995)
Notes	Interested students should send an email to filippo.delillo@unito.it

Title	*15- Experimental implementation of quantum devices*
Prof.	Jacopo Forneris, forneris@to.infn.it
CFU	2, 8 hrs
Period	September 2019 12/09/2019 h 14.00-16.00 aula Wick 13/09/2019 h 14.00-16.00 aula D 16/09/2019 h 14.00-16.00 aula Wick 17/09/2019 h 14.00-16.00 aula Verde
Goals	Luminescent defects in wide band gap materials are promising candidates for technological applications based on photonics and provide a viable path towards the practical realization of quantum devices. This course provides an introduction to the current trends in experimental quantum optics and material science, based on the fabrication and exploitation of single-photon sources for quantum information processing and quantum sensing.
Programme	1. Introduction to solid state quantum computing Qubits and block sphere quantum gates errors and decoherence Practical systems 2.Single-photon sources based on solid state defects Ideal single-photon sources Single-photon sources in wide band-gap materials Experimental methods for sources characterization: confocal microscopy and quantumness quantifiers Case studies and practical examples 3. Fabrication of of single-photon sources Motivation and challenges of deterministic implantation Techniques for high-resolution source placement Individual ion delivery and detection Formation yield 4. Technological applications of single-photon sources Integrated quantum devices Electrical control of single-photon sources Quantum sensing with individual spins in diamond Applications and examples
Bibliography	
Notes	

Title	*16- Case Studies in the History of Physics*
Prof.	Matteo Leone
CFU	2
Period	8 hrs, April-July 2019

Prerequisites	
Programme	The course covers one of the main topics in the historiography of physics: the importance of going back to the primary sources (archival documents, original papers, correspondence, instruments and so on). The topic will be assessed through the analysis of selected historical case-studies:- Macedonio Melloni and the birth of infrared physics (1830-1850) - “Rutherford’s experiment” on alpha particle scattering (1906-1913) - The collections of scientific instruments of historical interest: the Museum of Physics of the University of Turin and the SMA (University of Turin Museum System)
Bibliography	
Notes	Students who are willing to attend this course are **REQUESTED** to register by sending an email to Prof. Leone (matteo.leone@unito.it) before mid-March 2019

Title	**17. *Introduction to relativistic theory of cosmological perturbations***
Prof.	Stefano Camera,
CFU	3
Period	12 hours, TBD
Prerequisites	
Programme	0. The concordance cosmological model in a nutshell. 1. Basic notions of general relativity in an expanding universe. 2. Perturbations in cosmology. 2.a. Newtonian perturbation theory. 3. Gauge transformations and gauge-invariant variables. 4. Evolution of perturbations. 5. Structure formation. (6. The power spectrum of galaxy number counts.)
Bibliography	* Tsagas, Challinor & Maartens, "Relativistic cosmology and large-scale structure", Phys. Rept. 465, 61 (2008) * Malik & Wands, "Cosmological perturbations", Phys. Rept. 475, 1 (2009) * Camera et al., "The theory of relativistic cosmological observables", Phys. Rept. (2011, in prep.)
Notes	Interested students should send an email to prof. Camera, stefano.camera@unito.it

Title	**18-Search and characterization for extrasolar planets**
Prof.	Alessandro Sozzetti, sozzetti@oato.inaf.it
CFU	4
Period	16 hrs, TBD
Prerequisites	

Programme	-Elements of theory: planetary formation, internal structure and atmosphere, dynamic evolution; - Detection techniques, instrument limitations and astrophysics; - Observation of extrasolar planetary systems: statistical, structural and environmental properties - Observation of extrasolar planetary systems: the next 15 years.
Bibliography	

Title	***19-Chemo-dynamical evolution of the Milky Way***
Prof.	Alessandro Spagna(spagna@oato.inaf.it)
CFU	3
Period	12 hrs, TBD
Prerequisites	Fundamentals of Astronomy and Astrophysics
Programme	Structure, kinematics, and chemical properties of the Galactic stellar populations (disks, bulge, halo) Non axi-symmetric components: bar, spiral arms, flare, warp The hierarchical CDM galactic formation scenario Elements of Galactic dynamics and cosmological simulations of Milky Way-like disk galaxies Wide field stellar surveys (Gaia, RAVE, APOGEE, GES) Local cosmology: chemo-dynamical signatures of the Galactic formation processes
Bibliography	Binney & Merrifield, Galactic Astronomy

Title	**20-Advanced Topics in Higgs Physics**
Prof.	Andre David Tinoco Mendes, IST Lisbon and CERN
CFU	3
Period	12 hrs, 16-20 September 2019, Sala Fubini
Prerequisites	
Programme	16/9 -11-13: Nature 1 - 1 LHC (half-time). 17/9 -11-13: HEP detectors and triggers for Higgs physics. 18/9 -11-13: Higgs to diphoton - an analysis case study. 19/9 -11-13: Data visualisation and machine learning, part I. 19/9 -14-16: Data visualisation and machine learning, part II. 20/9 -11-13: Higgs experimental status
Bibliography	lectures

Title	**21-Advanced Perturbative QCD for Collider Physics**
Prof.	Eric Laenen, University of Amsterdam and Nikhef
CFU	3
Period	12 hrs, 30 September-4 October 2019, Sala Fubini
Prerequisites	

Programme	30/9 -11-13: Basics of QCD: from symmetry to phenomenology 1/10 - 11-13: Precision QCD: going beyond tree level. 2/10 - 11-13: Renormalisation and renormalisation group for QCD. 2/10 -14-16: Infrared issues in QCD and collinear factorisation. 3/10 - 11-13: All-order techniques for QCD amplitudes and cross sections. 4/10 - 11-13: QCD resummation and phenomenological applications
Bibliography	

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