PhD Physics course at Bari University (XXXIX Cycle)

Title	Gamma-ray Astrophysics in the Multi-messenger Context
Proponent	Elisabetta Bissaldi
# CFU (1 CFU = 8 hours)	2
Schedule	Sept - Nov 2024
Brief Summary of the course	This course aims to provide the student with advanced knowledge of gamma-ray astrophysics. It will explore the main properties of high-energy gamma-ray emitting sources, in particular Galactic sources like Pulsars and Supernova Remnants, and Extragalactic sources, like Active Galactic Nuclei (AGN) and Gamma-Ray Bursts (GRBs). GRBs also represent transient events, which, like AGN flares or nearby Solar Flares emitted by our Sun, can happen any time and require a strong monitoring strategy by all observatories. A brief overview of the currently operating space- and ground-based instruments and their operating principles will also be given. Finally, the course will focus on the multi-messenger aspect, including the association of short GRBs with gravitational wave events, and the observation of neutrino emission from the direction of known blazars during their flaring activity. It requires a background in basic high-energy astrophysics.
Program	Galactic and Extragalactic sources visible at gamma-ray energies: temporal and spectral characteristics. Multi-frequency studies. Transient phenomena in the gamma-ray sky. Gamma-ray instruments, detection of gamma radiation: scintillation detectors, pair-production telescopes, Cherenkov telescopes. Solar flares seen by Fermi at the dawn of the 25th Solar Cycle. The case of GRB 170817A / GW 170817 seen by Fermi, Swift and other observatories in the context of other LIGO/Virgo gravitational waves detections from 2015 to 2023, including the most recent results of the observing period O4 starting March 2023. The case of neutrino emission from the TXS 0506+056 as seen by IceCube, Fermi and MAGIC. Other recent examples.
Recommended texts	1. Spurio – "Probes of Multimessenger Astrophysics" 2. Longair - "High-energy astrophysics" 3. De Angelis & Pimenta - "Introduction to Particle and Astroparticle Physics" 4. Recent Publications
Assessment methods	Lectures; Final presentation.

PhD Physics course at Bari University (XXXVIII Cycle)

Title	Scintillators and Silicon Photomultipliers
Proponents	Elisabetta Bissaldi Serena Loporchio
# CFU (1 CFU = 8 hours)	2
Schedule	May - June 2024
Brief Summary of the course	This course aims to provide the student with advanced knowledge of radiation measurements and detection techniques, from classic scintillation detectors to Silicon Photomultiplier devices. It requires an elementary background in radiation measurements, radiation-matter interactions and basic electronics.
Program	The program includes Photon-matter interactions; Organic and Inorganic scintillators; Optical coupling; Solid-state photodetectors: The pn junction, the Photodiode, the SPAD, the SiPM. Different SiPM technologies. SiPM properties: single photoelectron resolution, gain, signal to noise ratio, photo-detection efficiency. Temperature dependence. The equivalent circuit of a SiPM. Optimal front-end: current feedback, pole zero cancellation network. SiPM arrays. SiPM coupled to scintillators. SiPM applications. Part of the course will be devoted to laboratory sessions.
Recommended texts	1. G. Knoll – "Radiation Detection and Measurement"; 2. Sedra & Smith – "Microelectronic Circuits" 3. Sze - "Physics of Semiconductor Devices" 4. Recent Publications
Assessment methods	Lectures; final laboratory report.

PhD Physics course at Bari University (XXXIX Cycle)

Title	Programming fundamentals using the C++ programming language
Proponent	Francesco Cafagna
# CFU (1 CFU = 8 hours)	2
Schedule	May-June (8, two hour long, lesson)
Brief Summary of the course	This course focuses on a basic introduction to the fundamental concepts founding programming using the C++ programming language. The C++ programming language - thanks to its general purpose, memory control, and strong type-check design – is a nice candidate to introduce to the concepts of programming native applications. The language base grammar, along with the base functionalities of features that make it well suited for an advanced programming with an object-oriented paradigm, will be treated. The core language feature will be interleaved with an overview of the major novelties introduced by the more recent standard updates.
Programme	**Lesson 1 and 2.** **Course introduction and layout:** - **Programming: an introduction.** - **Programming: base concepts.** - **Programming: the jargon.** - **Basic introduction to the tools and techniques used to build an executable.** **Lesson 3 and 4.** **The C++ base grammar:** - **Base types.** - **Expressions and statements.** - **Functions.** - **Pointer and reference.** - **Function overloading.** - **Examples and exercise.** **Lesson 5 and 6.** **C++ advanced functionalities:** - **Aggregate types: Structure.**

	- **Namespaces.** - **Template programming.** - **Examples and exercises.** **The STL (Standard Template Library) library:** - **General overview.** - **The iostream facility.** - **Containers.** **Lesson 7.** **Class:** - **An introduction and general properties.** - **Class members: creator, destructors, methods and helper functions.** - **Manage access to the class members: public, private.** - **Operators and overloading.** - **Modern C++. New Class design paradigm introduced since C++11.** - **Examples and exercises.** **Lesson 8.** **Class advanced functionalities:** - **Derived class.** - **Inheritance and polymorphism.** - **Examples and exercises.**
Recommended texts	- Lecture slides and examples. - B. Stroustrup, Programming -- Principles and Practice Using C++, Addison -Wesley ISBN 978-0321543721. December 2008. - B. Stroustrup, The C++ programming language (Third edition), Addison – Wesley - S. Lippman et al., C++ Primer (Fifth edition), Addison - Wesley
Assessment methods	A presentation and discussion on an exercise proposed by the student. The exercise will be related to the student research project, and use techniques, functionalities and tools threated during the course.

PhD Physics course at Bari University (XXXIX Cycle)

Title	Fundamentals in advanced programming using C++ programming language
Proponent	Francesco Cafagna
# CFU (1 CFU = 8 hours)	2 (8, two hours long, lessons)
Schedule	June-July
Brief Summary of the course	This course focuses on an introduction to the fundamental concepts founding the evolution from procedural to object-oriented programming. The C++ programming language - thanks to its general purpose, memory control, strong type-check design - will be used as a case study for such an evolution; for this the language functionalities that better adhere to the object-oriented paradigm, will be treated. The focus will be on the creation of user defined types and the core language feature will be interleaved with an overview of the major novelties introduced by the more recent standard updates.
Programme	**Lesson 1 and 2.** **Course introduction and layout:** - **From procedural programming languages to the object oriented ones.** - **Programming: an introduction.** - **Programming: base concepts.** - **Programming: the jargon.** - **Basic introduction to the tools and techniques used to build an executable.** **Lesson 3, 4 and 5.** - **An object oriented programming language: C++.** **Class:** - **Class members in depth: creator, destructors, methods and helper functions.** - **Move semantic and rvalue references.** - **Operators review and advanced features: type conversion.** - **Examples and exercises.** **Lesson 5, 6 and 7.** **Templates:**

	- **Template meta-programming.** **The Standard Template Library: STL.** - **An introduction and general properties.** - **In-depth view of the most popular STL facilities: string, containers, functionals and algorithms.** - **Modern C++ facilities: random generators, more type traits.** **Lesson 8.** **Hints on Object Oriented programming: some example of popular structural patterns.**
Recommended texts	- Lecture slides and examples. - B. Stroustrup, Programming -- Principles and Practice Using C++, Addison -Wesley ISBN 978-0321543721. December 2008. - B. Stroustrup, The C++ programming language (Third edition), Addison – Wesley - S. Lippman et al., C++ Primer (Fifth edition), Addison - Wesley
Assessment methods	A presentation and discussion on an exercise proposed by the student. The exercise will be related to the student research project, and use techniques, functionalities and tools threated during the course.

PhD Physics course at Bari University (XXXIX Cycle)

Title	Rare events Physics
Proponent	Giovanni Francesco Ciani
# CFU (1 CFU = 8 hours)	2
Schedule	To be agreed with the students
Brief Summary of the course	In order to go beyond the standard model and to explore new research frontiers, (Direct dark matter research, double beta decay neutrinoless, nuclear physics in region of interest of stellar evolution, exotic physics), it is mandatory to measure tiny signals with an extremely low event counting rate with respect to background. Therefore, it is crucial a correct analysis for cases with low S/N ratio. In this course, the main experimental and statistical techniques used in this research fields will be described. An overview of experiments as practical examples in laboratories all over the world (CERN, Laboratori Nazionali del Gran Sasso) will be described.
Programme	• **Main background source** and background reduction methods in low and high energy physics. • **Dark matter research**: experimental techniques used in direct research (dual-phase argon Time Projection Chamber, cryogenic scintillators, dark photon research). • **Double beta decay neutrinoless**: basic theoretical aspects and experimental techniques used in Underground Laboratories (HPGe detectors, Bolometric Scintillators) • **Exotics particle and rare decay research** • **Nuclear Astrophysics experiment** • **Data Analysis Tools in Rare Events Physics** (e.g. Pulse Shape Discrimination, Feldman Cousin Approach)
Recommended texts	Papers and review manuscripts; slides
Assessment methods	Presentation and discussion of a case of study

PhD Physics course at Bari University (XXXIX Cycle)

Title	Quantum Imaging
Proponent	Milena D'Angelo
# CFU (1 CFU = 8 hours)	2
Schedule	Eight two-hour lectures between June and July 2022
Brief Summary of the course	The course introduces the concept of quantum correlation, presents some typical correlated light sources, and discuss their role within several quantum imaging protocols.
Programme	Quantum entanglement. SPDC as a source of entangled photons. From classical to quantum imaging: Ghost imaging and diffraction with SPDC photons (Klyshko advanced wave model), and with classical light. Sub-shot-noise imaging. *Quantum metrology e super-resolution [CL].* Imaging by undetected photons. Single-pixel imaging. Imaging through turbulence and scattering media, imaging around corners. Correlation plenoptic imaging: from principles to applications.
Recommended texts	Scientific papers, PhD thesis, slides,
Assessment methods	ppt presentation on a topic related with the course.

PhD Physics course at Bari University (XXXVIII Cycle)

Title	Physics Future Colliders
Proponent	Patrizia Azzi (INFN Padova), Nicola De Filippis (Politecnico di Bari)
# CFU (1 CFU = 8 hours)	3
Schedule	January - March
Brief Summary of the course	This course covers the physics prospects of the proposed future collides machines currently under discussion and presented as part of the last European Strategy Update for Particle Physics. The projects discussed span from electron-positron colliders (linear and circular, at different center of mass energies from 90GeV to 3TeV), future hadron colliders (proton-proton but also considering the heavy-ion opportunities), electron-proton collider, muon collider and very high energy lepton colliders options. The course is organized exploring the physics measurement capabilities and sensitivity to new physics searches proposed by each project and their interpretation for the different type of particles colliding and center of mass energies. At the end of the course the student will be able to critically compare the pros and cons of the different projects from the physics reach standpoint. The course requires only a basic knowledge of the Standard Model. The course is appropriate, beyond particle physics students, also for theory, neutrino, nuclear physics and cosmology students that want to understand the future of the high energy particle physics field. The material is constantly updated every year with the most recent developments in the field.
Programme	The course is organized with 6 hours of lectures over 4 weeks, for a total of 24 hours/3 CFU. The initial introduction covers the current status of the latest measurement from LHC and the prospects for the HL-LHC, and the motivations behind the planning of future colliders machines. The course will start with the electron-positron colliders, exploring the opportunities given by the possibilities of having different center of mass energies from 90GeV up to 3TeV. It will cover the physics of electroweak processes at the Z pole and the WW threshold, then Higgs physics, top physics and the sensitivities for new physics searches. The physics at high energy hadron colliders will follow ($\sqrt{s}$=27TeV or 100TeV) also considering the possibility of colliding heavy ions. The physics opportunities at electron-proton colliders will also be described, and finally the prospects for the physics at muon collider and very high energy lepton colliders. The course will conclude with some considerations about the processes that the community of physicists employs to inform the future choices (European Strategy Update for Europe, or Snowmass for the USA).
Recommended texts	No specific texts are suggested. Sections of the the European Strategy Briefing Book and the Snowmass report can be useful to prepare the final exam.

Assessment methods	A presentation of about 20 min analyzing in a critical way the possibilities of studying a specific process at the various machines followed by a discussion.

PhD Physics course at Bari University (XXXIX Cycle)

Title	SM phenomenology and measurements
Proponent	S. Khalil (Zewail City of Technology University) N. De Filippis (Politecnico and INFN Bari)
# CFU (1 CFU = 8 hours)	3
Schedule	March – April 2024
Brief Summary of the course	This course provides an in-depth exploration of the theoretical and experimental foundations of the Standard Model, focusing on key concepts in quantum field theory, gauge theories, weak interactions and physics observable for direct and indirect SM measurements.
Programme	The lectures will cover the following topics: ▪ Theory of Quantum Electrodynamics (QED) and related measurements (α_S, PDF, etc…) ▪ Weak Interaction: From Fermi to V-A and related measurements (muon/pion decay lifetime and rate, etc.) ▪ Non-Abelian Gauge Theory and QCD ▪ Theory of Weak Interactions and Electroweak Unification and related measurements (discovery of the neutral current, discovery of the Z and W, etc.) ▪ Spontaneous Symmetry Breaking and Higgs Mechanism and related measurements (discovery of the Higgs and measurement of the properties) ▪ Glashow-Weinberg-Salam Model and related measurements (double Higgs searches and constraints) The lectures will be organized in March 2024 while Prof. Khalil will visit the Physics Department.
Recommended texts	S. Khalil and S. Moretti,"Standard Model Phenomenology," CRC Press, 2022, ISBN 978-1-138-33643-8

	R. Tenchini, C. Verzegnassi, “The Physics of the *Z* and *W* Bosons”, https://doi.org/10.1142/6465 | December 2007 Slides for experimental measurements and original articles for discovery and measurements.
Assessment methods	Lecture and possible tutorial sessions on specific aspects.

PhD Physics course at Bari University (XXXIX Cycle)

Title	Weak decays and effective Hamiltonians in the Standard Model and beyond
Proponent	Fulvia De Fazio
# CFU (1 CFU = 8 hours)	2CFU
Schedule	Spring-Summer 2024
Brief Summary of the course	I describe in detail the effective Hamiltonians for weak decays of mesons constructed using the operator product expansion and the renormalization group methods. Applications to rare decays in the Standard Model and beyond will be considered.
Programme	Construction of effective hamiltonians Renormalization group methods Weak decays: examples SMEFT
Recommended texts	A.~Buras, "Gauge Theory of Weak Decays" Cambridge University Press, 2020,
Assessment methods	oral exam

PhD Physics course at Bari University (XXXIX Cycle)

Title	Data Analysis in High Energy Physics
Proponent	Rosa Anna Fini
# CFU (1 CFU = 8 hours)	2
Schedule	April-May 2024
Brief Summary of the course	Modern (and old but still useful) concepts and tools to analyse data of nowadays high energy experiments are illustrated; fundamental of statistics, fitting, Monte Carlo are reviewed and explained; applications to real experimental procedures and practical problems are discussed.
Programme	Programming languages and analysis environments used in modern high energy experiments. Recall of Statistics and Probability. Monte Carlo technics. Events generators. Simulations and analysis of the interactions of particles in detectors. Reconstructions of events. Effective masses and Dalitz Plots. Parameters fittings, errors, interpretations. Experimental examples.
Recommended texts	G. Cowan, Statistical Data Analysis, Oxford University Press F. James, Monte Carlo theory and practice, Rep. Prog. Phys., Vol 43 (1980) 1145 F. James, Determining the statistical significance of experimental results, CERN Report DD/81/02 R. J. Barlow, Practical Statistics for Particle Physics, CERN Yellow Rep. School 559 Proc. 5 (2020) 149.
Assessment methods	Example of applications of one of the methods discussed in the course.

PhD Physics course at Bari University (XXXIX Cycle)

Title	Simulation of optical photon propagation for generic scintillator-based detectors
Proponent	Davide Serini (INFN) Serena Loporchio (PoliBA)
# CFU (1 CFU = 8 hours)	2
Schedule	May - June
Brief Summary of the course	Scintillator materials are widely used in particle physics for ion identification and energy measurements. Next-generation space missions will employ plastic scintillator detectors (PSDs) equipped with the new Silicon Photomultipliers (SiPMs) technology to read out the scintillator light emission. Scintillator based detectors are also widely used for radiation monitoring for environmental or industrial purposes. This course aims to provide the student with knowledge of radiation measurements and detection techniques. It will also provide the student the capability to implement a dedicated MC simulation of the performances of a generic scintillator-based detector using the GEANT 4 toolkit with hands-on sessions.
Programme	**Part 1 (Theoretical):** Absorption of radiation in scintillation materials. Light yield, organic and inorganic scintillators. Quenching effect and Birk's Law. Optical coupling. Solid state photodetectors: the Silicon Photomultiplier (SiPMs). Scintillator-based detectors application for space missions and for radiation environmental monitoring. **Part 2 (Hands-on sessions)** : An introduction to GEANT4 simulation toolkit. Make your own optical simulation project: the geometry, the physic list and the optical processes. Sensitive detector and optical photon hit. An introduction to ROOT toolkit: how to read the simulation results. Each topic will be correlated to progressive exercises aimed to make the student able to implement a complete simulation tool.
Recommended texts	- G. F. Knoll, "Radiation Detection and Measurement", ed. Wiley - Lecture notes. - Geant4 User's Documents page. - Root User's manual.
Assessment methods	Exercise sessions. Development of a simple project and discussion with an oral presentation.

PhD Physics course at Bari University

Title	Open quantum dynamics from Collision Models
Proponent	Dr. Maria Maffei (Università di Bari)
# CFU (1 CFU = 8 hours)	2
Schedule	8 class lectures between April and June
Brief Summary of the course	The course will provide basic concepts and tools for the derivation of Master Equations (MEs) of quantum systems, with a specific focus on Quantum Electrodynamics (QED) using Collision Models (CMs). CMs are microscopic system-bath models where the evolution is given by a sequence of repeated interactions, or collisions, between the system and different bath units. We will use as a playground the textbook case of a 2-level atom coupled with a waveguide field (the so-called 1D atom). CMs will be introduced in this context where they arise naturally from the Hamiltonian description, the atom being the system and the field being the bath. We will first derive Markovian MEs, e.g. Optical Bloch Equations, for classical field's states. Then we will consider genuinely quantum states of the field and derive non-Markovian MEs. In the last part of the course, we will treat the connection between CMs and quantum trajectories showing how CMs can be used to derive analytical joint atom-field wavefunctions in relevant experimental settings.
Programme	1. Collision model of the 1D atom. Noise operators. Collision model of the dipole interaction in the quasi-resonant, weak-coupling regime. Input-output formalism. Husimi Q functions and continuous-time heterodyne detection. 2. Markovian ME. Coherent thermal states of the field: derivation of the Optical Bloch Equations. Basics of quantum thermodynamics: work, heat and entropy production. 3. Non-Markovian ME. Single photon wavepackets and non-Markovian ME. 4. Quantum trajectories and atom-field wavefunctions. Exact solutions of some relevant light-matter scattering dynamics.

Recommended texts	Quantum collision models: open system dynamics from repeated interactions, F. Ciccarello, S. Lorenzo, V. Giovannetti, G.M. Palma, Physics Reports 954 ,(2022), Pages 1-70. https://doi.org/10.1016/j.physrep.2022.01.001
Assessment methods	Final seminar

PhD Physics course at Bari University (XXXIX Cycle)

Title	Hollow-Core Fiber Optics
Proponent	Giansergio Menduni
# CFU (1 CFU = 8 hours)	2
Schedule	II SEMESTER
Brief Summary of the course	The circular waveguide has found extensive use in optical communications systems as well as for single-mode laser beam delivery. This course provides a description of wave propagation in a circular waveguide and a detailed study of the coupling conditions between a laser beam and the optical modes of the waveguide. Chapter 1 deals with "step-index" fiber and propagation modes will be determined by solving the wave equation in cylindrical coordinates. In chapter 2, hollow-core waveguides (HCWs) will be introduced: they are composed of a capillary tube surrounded by a highly reflective inner wall. A theoretical discussion of laser-HCW mode coupling as well as waveguide propagation losses will be provided when the lowest order hybrid mode is excited within the HCW. The course ends with a laboratory activity consisting in an experimental study of a mid-infrared laser beam coupling with a cylindrical Ag/AgI HCW.
Programme	1. **Step-Index Waveguides.** The scalar Helmholtz equation. Homogeneous equation in Cylindrical Coordinates. Electric and Magnetic Field Distribution. Boundary Conditions. Hybrid Modes HE and EH. Linearly Polarized Modes LP. The Fundamental HE_{11} Mode. 2. **Hollow Core Waveguides.** Mode Analysis of a straight circular HCW. Metallic/Dielectric HCW. Attenuation Coefficient. Launch conditions and mode coupling. Propagation Losses. Single-mode output conditions. 3. **Laboratory activity.** Realization of a low-loss mode coupling of a Gaussian-like, mid-infrared laser beam with a silver/silver iodide HCW using a proper focusing lens. Measurement of propagation losses and analysis of the HCW output.
Recommended texts	Clifford R. Pollock, Michal Lipson - Integrated Photonics (2003, Springer) Xingcun Colin Tong - Advanced Materials for Integrated Optical Waveguides (2014, Springer)
Assessment methods	Report on laboratory activity

PhD Physics course at Bari University (XXXIX Cycle)

Title	P4ML - Python for Machine Learning: An introduction to Machine Learning Techniques and Deep Neural Networks with Python
Proponent	Giorgia Miniello, Ph. D.
# CFU (1 CFU = 8 hrs)	2
Schedule	February - June
Brief Summary of the course	The course is intended to enable the participants to use ML in their graduate research and to expose them to the state-of-the-art of ML. Explanation of, actual use of and limits of decision trees and neural networks will be emphasized. The course content comprises a short introduction to Python language and its main libraries used for ML methods, then an introduction to different types of learning in ML, fundamental type of ML models, starting from Perceptrons and evolving to Deep Neural Networks, along with enough learning theory to enable judicious use of ML.
Programme	The course includes a **first part** covering Python language and libraries used for ML methods, p**rinciples of machine learning** and the flow of the machine learning pipeline. In the **second part**, the classification as a supervised machine learning technique to predict discrete variable from a set of features or regression to predict continuous variables from a set of other variables will be explored. The student will discover how these methods and ensemble learning methods are applied to improve the accuracy of a prediction. The **third part** is an introduction to neural networks so to understand what neural networks are, its most successful applications, and how it can be used within a scientific context. The last step will include the exploration of the process of unsupervised machine learning techniques of clustering and dimension reduction as a means of learning from unlabelled data. The format will be two to 2&1/2 hours per week of seminar lecture/participation, but will be kept somewhat flexible so as to allow for development of the topic. Each student will pick a project to work on (presumably, but not required, to be a dissertation topic), and will present results to the class when requested. It is assumed that participants will bring their laptops to class and be prepared to download ML related software.
Recommended texts	We will use available Python-based software, supplemented by lecture notes.
Assessment methods	A project report will be the final written product of the seminar.

PhD Physics course at Bari University (XXXIX Cycle)

Title	Complex Fluids, non equilibrium and active systems: Theory and High performance computing applications
Proponent	Giuseppe Negro
# CFU (1 CFU = 8 hours)	2CFU
Schedule	Febraury-April 2024
Brief Summary of the course	The purpose of these lectures is to give an introductory overview on recent research developments in the field of applications of statistical and theoretical physics, and high performance computing to complex fluids, soft matter, and biological systems.
Programme	**Statistical physics and biological systems** -Active matter: The phase diagram of passive and active colloids. Topological transitions. -Biophysics: Polymer models of chromatin structure and genes transcription **Complex fluids** -Hydrodynamic modelling -Active emulsions. -Basic rheological behavior of complex fluids. -The yielding transition. **Simulations methods in soft and active matter** -Molecular dynamics -Lattice Boltzmann methods **Introduction to parallel computing** -Message Passage Interface(MPI) standard -Domain decomposition
Recommended texts	Lecture Notes

Assessment methods	Oral exam conducted as a seminar, focusing on a topic discussed in the lectures.

PhD Physics course at Bari University (XXXIX Cycle)

Title	Nuclear Techniques for Health
Proponent	PUGLIESE Gabriella, RAMOS LOPEZ Dayron
# CFU (1 CFU = 8 hours)	2
Schedule	
Brief Summary of the course	The course introduces basic concepts of nuclear physics applied in medicine, reaching advanced radio therapies and modern tools of particles simulation studies. It is divided in the follows main subjects: Introduction to interaction of radiation with matter and dosimetry, Radio isotopes in medical diagnosis, Gamma Camara, Computational tomography basics, PET/SPECT imaging techniques, Innovative radiation therapy with hadrons: HT and BNCT, and Monte Carlo on medical physics, Tool for Particle Simulation.
Programme	• **Introduction to interaction of radiation with matter and dosimetry**: Basic concepts, radioactivity. Interaction of heavy charged particles, stopping power, energy loss (Bragg curve, energy straggling), particle range. Fast electrons. Gamma rays, interaction processes. Neutron interactions, energy classification, neutron cross sections. Elements radiation exposure and dose, absorbed dose, dose equivalent, basic units, introduction to micro dosimetry concepts. • **Radio isotopes in medical diagnosis**: Radionuclide and radiopharmaceutical production, physics considerations for human health, physical properties. Radiopharmaceuticals for clinical applications, positron emitters. Theragnostic. • **Gamma Camara, Computational tomography basics**: Gamma Camara concepts, gamma detection, position and energy measurements, collimator types and effect, quantum efficiency, tomography reconstruction imaging. • **PET/SPECT imaging techniques**: SPECT principles, geometrical configurations, attenuation analysis, transmission scan concept, spatial resolution, volume sensitivity, applications. PET principles, annihilation processes, typical gamma detectors, Annihilation coincidence detection (ACD), time window, time resolution, sensitivity, events type.

	• **Innovative radiation therapy with hadrons: HT and BNCT:** Radio therapy concept, advantages of hadrons over gamma or electrons in cancer therapy, Hadron Therapy (HT) basics, ions production and acceleration systems, cyclotron and synchrotron principles, Spread-Out Bragg Peak, beam modulation, heavy ions advantages, Relative Biological Effectiveness (RBE), Lineal Energy Transfer (LET), FLASH therapy. Boron Neutron Capture Therapy (BNCT)principle, main nuclear reactions involved, neutron sources, accelerators based for BNCT (AB-BNCT), main targets in AB-BNCT, Beam Shape Assembly, AB-BNCT examples, dosimetry in BNCT, properties of BNCT agents. • **Monte Carlo on medical physics, Tool for Particle Simulation (TOPAS):** Monte Carlo methods, introduction to TOPAS, Parameter system, simulation structure, Geometry components, particles sources: beam definition, volumetric source, physics on TOPAS, modular physics lists, Scoring types: volume scorers, dose scorers, phase space scorer, medical examples.
Recommended texts	Physics in Nuclear Medicine, 4th Edition 2012, Simon R. Cherry, James A. Sorenson, Michael E. Phelps. Radiation Detection and Measurements, 4th Edition 2010, Glenn F. Knoll. TOPAS User Guide (http://topas.readthedocs.org/)
Assessment methods	Oral exam by seminary (PP presentation)

PhD Physics course at Bari University (XXXVIII Cycle)

Title	Artificial Intelligence for Social Good (AI4SG)
Proponent	Dr. Loredana Bellantuono (Università degli Studi di Bari Aldo Moro)
# CFU (1 CFU = 8 hours)	2
Schedule	8 class lectures in spring 2023
Brief Summary of the course	Artificial Intelligence for Social Good (AI4SG) is a new research field, that tackles important social, environmental, and public health challenges by using methods of complex system analysis, such as network models and machine learning. Using a top-down approach, AI4SG aims at delivering positive social impact in accordance with the priorities outlined in the United Nations' 17 Sustainable Development Goals (SDGs). The course has an application-oriented approach and is organized in tutorials focused on the analysis of relevant case studies related to the achievement of SDGs.
Programme	• Artificial Intelligence for Social Good (AI4SG): why and how. A primer on the main approaches to AI4SDG. The Python toolbox for big data analysis and visualization. • Complex systems and network science. Structure and properties of network graphs representing complex systems. • Case study 1 – Towards a more equitable education system (SDGs 4, 10). A complex network model to measure structural inequalities and territorial bias in the access to quality education. • Case study 2 – Social psychiatry (SDG 3). Investigating the impact of societal and environmental factors on the incidence of psychiatric disorders. • Machine Learning: predicting continuous variables with regression analysis. • Case study 3 – AI for the most vulnerable: interplay between hunger and climate change (SDGs 1, 2, 3, 13). Predicting food insecurity across sub-Saharan Africa with multivariate regression on data concerning prices, assets, and climate.

	• Natural Language Processing: preprocessing of text data, topic detection and sentiment analysis. • Case study 4 – The language of sustainability on social media (all SDGs). Topic modelling and sentiment analysis to unveil information from sustainability speech on Twitter.
Recommended texts	Sebastian Raschka, Vahid Mirjalili, "Python Machine Learning" – Packt Publishing Ltd (2017). Dmitry Zinoviev, "Complex Network Analysis in Python" – The Pragmatic Programmers, LLC (2018).
Assessment methods	Seminar on a selected topic or presentation of a project concerning Artificial Intelligence for Social Good (AI4SG).

PhD Physics course at Bari University (XXXIX Cycle)

Title	Machine Learning Techniques for Particle Physics
Proponent	Federica Maria Simone
# CFU (1 CFU = 8 hours)	2
Schedule	Spring 2024
Brief Summary of the course	The course will cover the use of machine learning techniques especially in the field of High Energy Physics (HEP) research. This course will provide students with a comprehensive introduction to Multivariate Analysis, Classification and Regression techniques, and how they can be applied to online data selection and offline data analysis in HEP. Students will be provided the necessary theoretical foundation and will gain practical experience through hands-on tutorials, which will include topics such as designing, training and evaluating decision trees, artificial neural networks, and hyperparameter optimization.
Programme	1. Introduction to machine learning and its applications in Physics data analysis 2. Supervised and unsupervised machine learning 3. Boosted Decision Trees, usage of the XGBoost python package 4. Convolutional Neural Networks and Autoencoders, implementation in TensorFlow using Keras 5. Deep Neural Networks with Pytorch
Recommended texts	Material provided by the lecturer (slides and notebooks).
Assessment methods	Final hands-on exercise and discussion.

PhD Physics course at Bari University (XXXIX Cycle)

Title	Nuclear Astrophysics
Proponent	Giuseppe Tagliente
# CFU (1 CFU = 8 hours)	2
Schedule	February - April
Brief Summary of the course	The nuclear processes generate the energy that makes stars shine. The same processes in stars are responsible for the synthesis of the element present in the universe. Nucleosynthesis, energy production in the stars, and other topics overlapping astrophysics and nuclear physics makeup the science of nuclear astrophysics. Like most fields of physics, it involves both theoretical and experimental activities. The purpose of this course is to explain these concepts with special emphasis on nuclear processes and their interplay in the stars
Programme	Lesson 1. Aspects of nuclear physics and astrophysics. Lessons 2-3. Nuclear and thermonuclear reactions Lessons 4-6. Processes of Nucleosynthesis Lessons 7-8. Nuclear physics experiments for astrophysics
Recommended texts	Material will be provided by the lecturer
Assessment methods	Seminar on an agreed topic

PhD Physics course at Bari University (XXXIX Cycle)

Title	FPGA programming with LabVIEW
Proponent	Giuseppe Tagliente
# CFU (1 CFU = 8 hours)	2
Schedule	May - June
Brief Summary of the course	The purpose of the course is to broaden the knowledge of LabVIEW to program the field-programmable gate array (FPGA). A knowledge of LabVIEW is required
Programme	**Lesson 1**. Concepts of FPGA **Lesson 2**. Programming FPGA with LabVIEW **Lesson 3**. Applications of FPGAs **Lesson 4.** Laboratory, implementation of a code to control a DAC
Recommended texts	Material will be provided by the lecturer
Assessment methods	The students have to present a code based on FPGA

PhD Physics course at Bari University (XXXIX Cycle)

Title	Advanced Technologies for Data Analysis
Proponent	Gioacchino Vino
# CFU (1 CFU = 8 hours)	2
Schedule	May-June 2024
Brief Summary of the course	Technologies should go at the same pace of Data sample size and Machine Learning model complexity, in order to keep the execution times acceptable. Python is a language that makes data analysis easier thanks to its large amount of available tools. Advanced Python libraries (e.g. PyTorch, TensorFlow, Keras) are available to speed up specific phases of the Machine Learning application. Big Data and GPU based libraries could provide further improvements in the execution time, distributing computation on a cluster of machines. This course will cover all these topics including some examples of platforms capable to support the data scientist during all Machine Learning lifecycle. This course does not provide any Machine Learning concepts and only focuses on technologies, so please take Machine Learning courses before where basic principles are introduced.
Programme	- Python tools for science - Tabular Data Structure - Frameworks for Data Analysis - Big data and parallel computing in Data Analysis - Platforms supporting Machine Learning lifecycle
Recommended texts	
Assessment methods	Discussion of hands-on exercise