Università degli Studi di Padova

PHD OF NATIONAL INTEREST IN TECHNOLOGIES FOR FUNDAMENTAL RESEARCH IN

PHYSICS AND ASTROPHYSICS

EDUCATIONAL OFFER – A.Y. 2024/25

Curriculum: ELECTRONICS

- High-energy Particle Physics Detectors in Space
- HE-5: Front-end and readout electronic systems for High Energy Astroparticle Physics
- Cosmic radiation and radiation hardness assurance
- Rare event search with noble liquids
- Cryogenic sensors for Astroparticle Physics
- Low Energy Radiation Measurements (Lab Course)
- Cabling and Shielding for low noise applications
- Advanced electronic sensing devices
- Design of readout integrated circuits for Particle Detectors
- Advanced scientific programming in Matlab
- Numerical Simulation of Electronic Devices with TCAD (Technology Computer Aided Design) Tools for high energy physics applications
- Programmable System on Chip (SoC) for data acquisition and processing
- Fundamentals of system engineering and project management for large scientific projects
- Optical Fiber Systems M

- Electronic systems in high energy physics
- Simulation of optical photon propagation for generic scintillator-based detectors
- Microelectronics for radiation detectors II
- Fundamental of FPGA-based digital design
- Advanced FPGA design and design management techniques

Course unit English denomination	High-energy particle physics detectors in space
Teacher in charge (if defined)	Dott.ssa Loporchio Serena
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	January/February
Course delivery method	☐ In presence ☐ Remotely ☐ X Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☐ X No
Course unit contents	Basic elements of particle physics. Radiation-matter interaction Basic knowledge of astroparticle physics Detectors for space applications (scintillators, photodetectors, silicon detectors) Space qualification tests
Learning goals	Know the instruments for detecting high-energy particles used in aerospace Know the verifications and tests required for instrumentation validation
Teaching methods	Lectures with slides
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☐ X No
Available for PhD students from other courses	☐ X Yes ☐ No
Prerequisites (not mandatory)	Basic knowledge of particle physics
Examination methods (in applicable)	Oral presentation
Suggested readings	Slides Knoll, Radiation detection and measurements
Additional information	-

Course unit English denomination	HE-5: Front-end and readout electronic systems for High Energy Astroparticle Physics
Teacher in charge (if defined)	Felicia Barbato, Adriano Di Giovanni
Teaching Hours	15
Number of ECTS credits allocated	2
Course period	March-april (TBD)
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	Waveforms and signal processing. Front End electronics. Review of electronics systems for signal conditioning. Signal charge collection in low power regimes. Data processing and decoding. Radiation hardness. Specific examples on space-based detectors. Hands-on sessions with signal simulation tools.
Learning goals	Acquisition and processing of particle detector signals
Teaching methods	Slides and hands-on
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-
Examination methods (in applicable)	Exercises and oral discussion
Suggested readings	-

Additional information	-

Course unit English denomination	Cosmic radiation and radiation hardness assurance
Teacher in charge (if defined)	Dr. Pierluigi Casolaro
Teaching Hours	15
Number of ECTS credits allocated	2
Course period	December 2024 – February 2025
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	The course focuses on the study of radiation effects on materials and electronic components used in space missions. It begins with a description of the space environment, highlighting the main sources of radiation, such as particles trapped in the Van Allen belts, galactic cosmic rays, and particles from the Sun. Then, the interaction of radiation with matter and dosimetry are discussed. This is followed by a study of the main types of radiation damage: Total Ionizing Dose (TID), Displacement Damage Dose (DDD), and Single Event Effects (SEE). In addition to the damage to material and electronics, biological effects of radiation are discussed with a focus on the safety of space crew, providing basic concepts of radiation protection. Finally, the course discusses the characteristics of the facilities and laboratories, as well as the protocols for performing Radiation Hardness Assurance tests.
Learning goals	The course aims to provide the basic tools for performing Radiation Hardness Assurance tests. To this end, the goal is to acquire or consolidate knowledge of the interaction between radiation and matter, as well as dosimetry, which are necessary for understanding the main effects of radiation on electronics and humans (radiation protection in space environments and in laboratories for radiation testing).
Teaching methods	The lectures will be conducted in person and supported by slides prepared by the lecturer. Practical exercises will be carried out using the simulation software "Space Environment, Effects, and Education System" (SPENVIS).
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No

Prerequisites (not mandatory)	
Examination methods (in applicable)	The final examination will include a discussion on the topics covered during the course, optionally starting from a specific topic chosen by the student related to his/her PhD project
Suggested readings	Lectures will be supported by the projection of slides prepared by the lecturer. For the study of the interaction of radiation with matter and dosimetry, the following texts will be used as a reference: • C. Leroy and P.-G. Rancoita, Principles of Radiation Interaction in Matter and Detection (World Scientific, Singapore, 2011) • P. Mayles, A. Nahum, and J.-C. Rosenwald, Handbook of Radiotherapy Physics: Theory and Practice (CRC Press, Boca Raton, 2007)
Additional information	

Course unit English denomination	Rare event search with Noble Liquids
Teacher in charge (if defined)	Paolo Agnes
Teaching Hours	12
Number of ECTS credits allocated	2
Course period	April - May 2025
Course delivery method	☐ In presence ☐ Remotely X Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) X No
Course unit contents	- Working principles of single and double phase experiments for dark matter searches and neutrino physics: 1.Physics of signals creation and detection, focus on recent developments of the scintillation light detection technology; 2. Challenges to calibrate detectors, identify and suppress backgrounds; 3. Review the rich physics program.
Learning goals	- Understanding the working principle, characteristics and limitations of different noble liquid detectors
Teaching methods	Lectures with slides, one hands-on session on real data analysis
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes X No
Available for PhD students from other courses	X Yes ☐ No
Prerequisites (not mandatory)	Radiation-matter interaction basics Particle physics basics
Examination methods (in applicable)	Seminar on an agreed topic followed by questions and a short discussion
Suggested readings	Slides of the course Knoll - Radiation detection and measurement, Wiley
Additional information	

Course unit English denomination	Cryogenic sensors for astroparticle physics
Teacher in charge (if defined)	Andrei Puiu
Teaching Hours	12
Number of ECTS credits allocated	2
Course period	April - May 2025
Course delivery method	☐ In presence ☐ Remotely X Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) X No

Course unit contents	- Low Temperature Matter Behavior
	- Thermal Sensors and Their Operation
	    - Semiconductor Thermistors
	    - Transition Edge Sensors
	    - Kinetic Inductance Detectors
	    - Metallic Magnetic Calorimeters
	- Applications in Astroparticle Physics

Learning goals	- Understanding the working principle and characteristics of different thermal sensors - Understanding the different applications of thermal sensors in the field of rare event research
Teaching methods	Lectures with slides
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes X No
Available for PhD students from other courses	X Yes ☐ No
Prerequisites (not mandatory)	Radiation-matter interaction basics Particle physics basics

Examination methods (in applicable)	Seminar on an agreed topic followed by questions and a short discussion
Suggested readings	Slides of the course
Additional information	

Course unit English denomination	Laboratory of low-energy radiation measurement
Teacher in charge (if defined)	Andrei Puiu - Lorenzo Pagnanini
Teaching Hours	20
Number of ECTS credits allocated	5
Course period	May - June 2025
Course delivery method	X In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	X Yes (60% minimum of presence) ☐ No
Course unit contents	- Measurement of low-energy radioactivity with High Purity Germanium detectors and low temperature scintillators (from 20 to 300 K). This is a laboratory course that includes the detector installation and operation at LNGS external laboratories, as well as data taking and analysis.
Learning goals	- Understanding the working principle and characteristics of different thermal sensors - Understanding the different applications of thermal sensors in the field of rare event research
Teaching methods	Laboratory
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes X No
Available for PhD students from other courses	X Yes ☐ No
Prerequisites (not mandatory)	Radiation-matter interaction basics Particle physics basics
Examination methods (in applicable)	Seminar on an agreed topic followed by questions and a short discussion
Suggested readings	Knoll - Radiation detection and measurement, Wiley
Additional information	

Course unit English denomination	Cabling and shielding for low noise applications
Teacher in charge (if defined)	Alberto Aloisio
Teaching Hours	10
Number of ECTS credits allocated	1.25
Course period	Tbd, in the II semester
Course delivery method	☐ In presence ☒ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (70 % minimum of presence) ☐ No
Course unit contents	Characteristics of the most commonly used cabling techniques (coax, twisted-pairs, triax, ...) Analysis of capacitive and inductive coupling phenomena Analysis of the performance achievable with different interconnection schemes Ground loops Moderation of unwanted electromagnetic emissions Grounding non-ideality and effects on sensor read-out Analysis of differential connections
Learning goals	evaluate the source and characteristics of the aggressor signals choose the most appropriate wiring scheme for the specific application evaluate the impact of different grounding schemes know and apply differential interconnection schemes
Teaching methods	Frontal teaching
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-
Examination methods (in applicable)	Oral test

Suggested readings	Textbooks and slides
Additional information	-

Course unit English denomination	Advanced Electronic Sensing Devices
Teacher in charge (if defined)	Andrea De Iacovo
Teaching Hours	15
Number of ECTS credits allocated	2
Course period	November-December
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	The course focuses on advanced sensors and transducers for electronic applications. The working principle of several different types of electronic sensors and their integration strategies with electronic systems will be discussed. At the end of the course, students will gain advanced knowledges about the working principles of several different classes of sensors with a strong focus on innovative devices and applications.
Learning goals	The course gives a landscape view of advanced electronic sensing devices, providing the students with information about the working principles and physical characteristics of different classes of sensors. The students are expected to gain advanced knowledge about electronic sensors for different fields of application and about readout circuits.
Teaching methods	Frontal lessons and laboratory session
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-
Examination methods (in applicable)	Final report

Suggested readings	Study materials is provided by the Professor.
Additional information	-

Course unit English denomination	DESIGN OF READOUT INTEGRATED CIRCUITS FOR PARTICLE DETECTORS
Teacher in charge	Flavio Loddo (INFN Bari) Francesco Licciulli (INFN Bari)
Teaching Hours	20
Number of ECTS credits allocated	2.5
Course period	November 2024
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	The aim of this course is to illustrate a typical design flow of an Application Specific Integrated Circuit (ASIC) to read-out particle detectors: chip floorplan, design and simulation of the analog blocks and digital control and read-out logic and full chip verification. Starting from the analysis of the project specifications and, in particular, the type of sensor and the physical quantities to be measured (energy, time), various analog front-end architectures will be shown together with different digital architectures. In addition, the problem of radiation hardness will be addressed, combining the choice of the most adequate technology for the specific application to the commonly used mitigation techniques for both analog and digital circuits.
Learning goals	The student will acquire a basic knowledge of the problems related to the design of an integrated circuit for the readout of detectors for high energy physics.
Teaching methods	Lectures with the help of slides and EDA demonstrations by the teacher
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Basic knowledge of analog and digital electronics

Examination methods (in applicable)	Oral
Suggested readings	Slides; bibliography referenced in the slides
Additional information	-

Course unit English denomination	Advanced scientific programming in Matlab
Teacher in charge (if defined)	Paolo Bardella, Stefano Scialò
Teaching Hours	30
Number of ECTS credits allocated	6
Course period	January/February 2025
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	1.5h: introduction to MATLAB, with particular attention on the improvements introduced in the latest versions 1.0h: source Control systems integrated in MATLAB (git) 1.5h: MATLAB internals: data structures, JIT, numerical libraries 3.0h: object oriented programming in MATLAB 3.0h: optimization of MATLAB code, use of the Code Profiler 3.0h: MEX files for the execution of C/C++ and Fortran code in MATLAB. MATLAB C code generator 3.0h parallel computing in MATLAB: introduction to parallel computing, commands parfor, spmd, advantages and limitations. 3.0h: GPUs in MATLAB: introduction to GPUs and gpuarray command 3.0h: optimization of I/O in MATLAB, control of hardware 3.0h: fundamentals of machine learning in MATLAB; Big data and tall arrays 1.0h: alternatives to MATLAB: python, Arrayfire, Gnu Scientific library, Octave, Scilab 4.0h: projects' presentation
Learning goals	The course aims to provide advanced skills in scientific programming, and to teach sound methodologies for the development of reliable, optimized and maintainable codes. During this course, many common methods used in Scientific Computing will be presented, with particular attention to the most recent programming techniques in MATLAB. At the end of the course, the student will have expanded his/her knowledge of MATLAB and will be able to choose the best approach for the solution of numerical problem he/she will face.
Teaching methods	Lectures
Course on transversal, interdisciplinary,	☒ Yes ☐ No

transdisciplinary skills	
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Basic knowledge of MATLAB language.
Examination methods (in applicable)	Presentation of group activity on the optimization of existing MATLAB code proposed by the students.
Suggested readings	Slides provided by the teachers, video recordings of the lessons, suggested texts on specific topics.
Additional information	-

Course unit English denomination	Numerical Simulation of Electronic Devices with TCAD for High Energy Applications
Teacher in charge (if defined)	Prof. Daniele Passeri (UNIPG), Arianna Morozzi (INFN-PG)
Teaching Hours	20
Number of ECTS credits allocated	2.5
Course period	June 2025
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	The topics that will be covered will be: • Fundamentals of electronic devices. • Numerical simulation: physical models and numerical methods. • Process simulation. • Device simulation (device level and mixed simulations). • Analysis and interpretation of results.
Learning goals	Upon completion of this course, PhD students will be able to: • Master the Technology-CAD tools by becoming familiar with the main semiconductor detector development tools. • Design the layout of semiconductor devices of various geometries and complexity. • Perform device-circuit simulations aimed at characterising static (DC) and dynamic (TV) performance in order to optimise performance. • Analysing the results of simulations by interpreting the results and correlating the electrical characteristics of the device with its physical structure. • Simulate the effect of variations in process parameters on device performance and assess the robustness of the design.
Teaching methods	Theoretical lectures will alternate with practical sessions in which students can simulate the design flow of a solid-state detector.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No

Prerequisites (not mandatory)	None.
Examination methods (in applicable)	The final examination will consist of the presentation and discussion of an end-of-course project.
Suggested readings	Slides and supplementary material provided by the course lecturers.
Additional information	-

Course unit English denomination	Programmable System on Chip (SoC) for data acquisition and processing
Teacher in charge (if defined)	Andrea Fabbri
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	The course will introduce the latest generation programmable devices (FPGA and ACAP) describing their characteristics and main modules (DDR management, integrated processors, DSP, AI engine...) and their interaction. Use cases will then be presented and a classroom project will be carried out aimed at learning the methodologies for using these complex systems in the field of data acquisition systems (DAQ) for physics and astrophysics equipment.
Learning goals	The main objective is to give the student a vision of the tools currently available on the market that can be used in the context of complex data acquisition systems. The student will be provided with the methodologies for the architectural design of such systems through the use of such platforms and hints on the relative programming methods.
Teaching methods	The course includes an introductory part in which the basic concepts related to the needed functionality of an acquisition systems. Moreover, the components integrated within a modern FPGA will be discussed and recalled. Two case studies will then be viewed in the classroom as an example of complex acquisition systems based on programmable devices.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-

Examination methods (in applicable)	Oral interview (By appointment)
Suggested readings	handouts provided by the teacher
Additional information	-

Course unit English denomination	Fundamentals of system engineering and project management for large scientific projects
Teacher in charge (if defined)	Marco Xompero / Runa Briguglio
Teaching Hours	12
Number of ECTS credits allocated	1,5
Course period	spring 2025
Course delivery method	x In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	x Yes (100% minimum of presence) ☐ No
Course unit contents	Today, scientific research projects are carried out by large international teams and involve a multi-disciplinary approach. In add, specific tools are requested: to organize the team-work, to meet the deadlines, to define a common language and comprehension across all the elements in the project. The system engineer and the project manager are key-figures in the organizational chart. System engineering is an approach for successful systems, focusing on the early analysis of the user needs, then proceeding with design synthesis and system validation considering the complete problem. Project management, in parallel, is related to the organizational aspects: the definition of who will be doing what and how, the creation and optimization of a project calendar, based on the activities prioritization and their conflicts, the identification and management of risks, and much more. The class is intended to provide PhD students with a basic package to understand the project's working mechanisms.
Learning goals	Project planning System management
Teaching methods	Slides and group work, analysis of use cases. The course is organized as a 2, 3 days workshop in Florence
Course on transversal, interdisciplinary,	x☐ Yes No

transdisciplinary skills	
Available for PhD students from other courses	☐ Yes x No
Prerequisites (not mandatory)	None
Examination methods (in applicable)	class work, organization of a custom project.
Suggested readings	None. References will be given during the classes
Additional information	https://sites.google.com/inaf.it/syseng-phdnazionale/home-page

Course unit English denomination	Optical Fiber Systems M
Teacher in charge (if defined)	Giovanni Tartarini
Teaching Hours	60
Number of ECTS credits allocated	6CFU
Course period	February 2025 – June 2025
Course delivery method	☒ **In presence** ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	**Module 1: "Generation, Transmission and Processing of Optical Signals"** Optical fiber: main characteristics • Modal Propagation in the dielectric slab. TE and TM modes • Modal propagation in dielectric waveguides. Optical fiber. • Single-mode and Multi-mode Optical Fibers; Plastic Optical Fibers • Phase and group velocity. Transmission impairments. Attenuation, Dispersion, Nonlinear effects Optical Transmitters and Receivers • LEDs, LASERs and Optical Transmitters • PINs, APDs and main types of Direct Detection Receivers. • Receivers for Coherent Systems Active and Passive Optical Components and Devices for Telecommunications and Sensors • Scattering and Transmission Matrix concepts. • Fabry-Perot cavity, Optical filters, Diffraction Gratings. Fiber Bragg Gratings. • Optical Multiplexers and Demultiplexers, Add and Drop filters • Directional Couplers, Splitters, Circulators • Optical Amplifiers, Cross-gain Modulation and Wavelength Conversion • Mach Zehnder and Electro-Absorption Optical Modulators **Module 2: "Outdoor and In-Building Optical Systems"** Optical Transmission Systems for Metro Area Networks and for the Access Network • Fundamental concepts, figures of merit and design parameters. • Fiber to the Node/Curb/Building/Home (FTTx) solutions. • Point to Point, Point to Multipoint and Hybrid schemes. • Examples of FTTH systems design in real environments, including existing infrastructure exploitation, and cost evaluations

	Optical Transmission Systems for the Transport Network • Fundamental concepts on digital optical links, figures of merit and design parameters. • OOK Systems, DQPSK Systems, Coherent Systems • Optical transmission systems for In-Building Scenarios Fundamental concepts on RF-over-fiber systems, figures of merit and design parameters. • In-Building Fiber Distributed Antenna Systems (F-DAS): characteristics and design aspects. • Fiber-based distribution of mm-wave signals: solutions and trends.
Learning goals	Knowlegde of the operation of the building blocks of optical communication systems, aimed to their basic design in different realistic scenarios.
Teaching methods	Traditional Blackboard Laboratory activities Exercises solved in class for training.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ **No**
Available for PhD students from other courses	☒ **Yes** ☐ No
Prerequisites (not mandatory)	Basics on Electromagnetic fields propagation
Examination methods (in applicable)	Written exam followed by an Oral part. In case of PhD students the only oral part can be taken.
Suggested readings	Gerd Keiser, "Optical Fiber Communications", Mc Graw Hill
Additional information	

Course unit English denomination	Electronic systems in high energy physics
Teacher in charge (if defined)	Adriano Lai
Teaching Hours	36
Number of ECTS credits allocated	4
Course period	Second semester
Course delivery method	☐ In presence ☐ X Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ X Yes (70% minimum of presence) ☐ No
Course unit contents	Basics part: Pixel detector reading system from sensor to A/D conversion (mainly a recall). Advanced part: Study of a space-time (4D) tracker for high-intensity high-energy physics experiments. Issues and solutions from sensor design to precision time measurements
Learning goals	Understanding the details of operation of a tracker for next-generation collider experiments from a system perspective
Teaching methods	Frontal lessons. Practical examples
Course on transversal, interdisciplinary, transdisciplinary skills	☐ X Yes ☐ No
Available for PhD students from other courses	☐ X Yes ☐ No
Prerequisites (not mandatory)	-
Examination methods (in applicable)	Written report on an assigned theme
Suggested readings	Slides and reference papers
Additional information	-

Course unit English denomination	SIMULATION OF OPTICAL PHOTON PROPAGATION FOR GENERIC SCINTILLATOR-BASED DETECTORS
Teacher in charge (if defined)	Dott. Davide Serini (INFN Sezione di Bari)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	2 Semester (May-July)
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	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. ***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.
Learning goals	Understand the base classes to implement a generic simulation using the Geant4 toolkit. Understand the operating principles of detectors based on scintillators and photosensors. Implement a simple simulation involving optical processes.
Teaching methods	Lectures with slides support. Progressive exercises aimed to make the student able to implement a complete simulation tool.

	The course can be fully attended online through live Zoom lectures. Course materials, including lectures, example codes, and exercises, will be shared via a common repository accessible to all students. A comprehensive guide for installing all the necessary software will be provided before starting the course. Communication within the class will be managed through a dedicated mailing list.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Basic knowledge of C++ programming
Examination methods (in applicable)	Exercise sessions. Development of a simple project and discussion with an oral presentation.
Suggested readings	- G. F. Knoll, “Radiation Detection and Measurement”, ed. Wiley - Lecture notes. - Geant4 User's Documents page. - Root User's manual.
Additional information	

Course unit English denomination	Microelectronics for radiation detectors II
Teacher in charge (if defined)	Giovanni Mazza (INFN-Sezione di Torino)
Teaching Hours	24
Number of ECTS credits allocated	3
Course period	Second semester (May-July)
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	The scope of the course is to provide a more in depth treatment of integrated electronics for radiation sensors, with emphasis on electronics for single photon, X-ray and charged particles detectors. The course outlines the key issues about radiation damage in integrated circuits, with particular emphasis on applications with particle accelerators and aerospace. The implications of radiation tolerant in the design of key building blocks in radiation detection system such as time-to-digital converters, phase-locked loops, ADCs and memories is discussed.
Learning goals	Understanding the details of design of critical building blocks, such as ADC, TDC and PLL that have to operate in harsh environmental conditions
Teaching methods	Lectures covering theoretical aspects and discussions of practical case studies
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Basic knowledge in circuit theory and CMOS technology
Examination methods (in applicable)	Oral presentation on a topic agreed with the teacher

Suggested readings	Slides prepared by the teacher and key papers with a detailed list given at the beginning of the course
Additional information	Course borrowed from the Doctorate in Electrical, Electronic and Communications Engineering of the Polytechnic University of Turin

UNIVERSITÀ DEGLI STUDI DI PADOVA

CORSI DI DOTTORATO

Course unit English denomination	Fundamental of FPGA-based digital design
Teacher in charge (if defined)	Christian Zambelli (University of Ferrara), Nicolo' Vladi Biesuz (INFN-Ferrara)
Teaching Hours	20
Number of ECTS credits allocated	2,5
Course period	Second semester (May-July)
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	- Introduction to integrated electronic systems: the concept of analog, digital, and mixed-signal electronic system, possible scenarios of integration, design constraints (power consumption, area occupied, cost), design flow, prototyping systems, and boards - The programmable logic (FPGA): macro-block structure, integrated implementation of an FPGA, programming an FPGA using a hardware description language (VHDL), synthesis and implementation of a design, evaluation boards - The IDE Xilinx Vivado: how to do a first project in VHDL of an integrated electronic system, the difference between simulation (test bench) and implementation, communications with an evaluation board and its peripherals (LED, switches and push button) - Construction of a hierarchical integrated electronic system: example of a hardware adder, entity concept and module in VHDL, reuse of resources, an example of a PWM modulator - I/O Management: multiplexing I/O with other devices, driving and acquisition of signals using ADC integrated into FPGA, communication with the human interface device (HID) through the USB port
Learning goals	Providing an introduction to digital design based on FGPA, allowing the sudents to address the implementation of firware project of moderate complexity
Teaching methods	Lectures covering theoretical aspects and discussions of practical case studies
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No

Prerequisites (not mandatory)	Basic knowledge of digital circuit and programming is not mandatory, but it is an advantage
Examination methods (in applicable)	Oral presentation on a topic agreed with the teacher
Suggested readings	Slides prepared by the teachers
Additional information	-

Course unit English denomination	Advanced FPGA design and design management techniques
Teacher in charge (if defined)	Enrico Calore (INFN-Ferrara), Nicolo' Vladi Biesuz (INFN-Ferrara)
Teaching Hours	20
Number of ECTS credits allocated	2,5
Course period	Summer-Autumn 2025
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	PROGRAM: - Advanced design techniques: introduction to HLS and application examples based on AMD/Xilinx FPGA and the Vitis HLS tool of the Vivado development suite. - Versioning and maintenance tool for FPGA designs: - Introductory course on TCL scripting - Source code versioning using git and introduction to the concept of continuous integration - Firmware and git: peculiarities and properties
Learning goals	The course covers advanced topics on FPGA design, introducing also the students to high-leve syntehsis design methodology
Teaching methods	Lectures covering theoretical aspects and discussions of practical case studies
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	The student should be familiar with basic-to-indermediate firmware developments concepts and/or passed successfully the basic course
Examination methods (in applicable)	Oral presentation on a topic agreed with the teacher

Suggested readings	Slides prepared by the teachers
Additional information	-