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: DETECTORS, LASERS AND OPTICS

- Photodetection: Scintillators and Silicon Photomultipliers
- High-energy particle physics detectors in Space
- New Technologies for Cherenkov telescopes
- 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)
- High Energy Radiation Measurements (Lab course)
- Cabling and Shielding for low noise applications
- Advanced electronic sensing devices
- Gaseous Detectors for Experimental Particle Physics
- Advanced scientific programming in Matlab
- Semiconductor light sources for engineers
- 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
- Vacuum Technologies
- Adaptive Optics for Astronomy
- Radio and Optical Inteferometry
- Fundamentals of System Engineering and Project Management for large
- scientific projects
- Electronic systems in high energy physics
- Simulation of optical photon propagation for generic scintillator-based detectors
- Novel detectors for future experiments at collider
- Radiation Matter Interaction
- Physics with High Energy particle detectors: from photographic plates to the LHC experiments
- Solid State Detectors
- Metodologies and techniques for the analysis of experimental data
- Adaptive Optics for Astronomy II
- Project Management in science

Course unit English denomination	New technologies for Cherenkov telescopes
Teacher in charge (if defined)	Dott.ssa Loporchio Serena
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	March/April
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	Development of Extensive Air Shower Operating Principles of Cherenkov Telescopes Detection Techniques and Instruments (PMT, SiPM) Readout Electronics Image reconstruction
Learning goals	Advanced knowledge of technologies currently used in Cherenkov telescopes and future technologies under development
Teaching methods	Lectures with slide support
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒No
Available for PhD students from other courses	X Yes ☐ No
Prerequisites (not mandatory)	Basic knowledge of high-energy astrophysics and detector physics
Examination methods (in applicable)	Oral presentation
Suggested readings	Slides De Angelis and Pimienta, Introduction to Particle and Astroparticle Physics. ISBN 978-3-319-78180-8. Springer International Publishing AG Spurio, Probes of Multimessenger Astrophysics. ISBN 978-3-319-96853-7. Springer Nature Switzerland AG, 2018 Knoll, Radiation detection and measurement, New York, John Wiley and Sons, Inc.,

	1979
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	Laboratory of high-energy radiation measurement
Teacher in charge (if defined)	Felicia Barbato - Adriano di Giovanni
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	- Silicon-based light detectors. Readout and DAQ systems. Applications to space-based experiments. Tracking systems: measurement of observables and diagnostics. This is a laboratory course: lectures will be held at the Gran Sasso National Laboratory (LNGS)
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	Gaseous Detectors for Experimental Particle Physics
Teacher in charge (if defined)	Rosamaria Venditti (Uniba), Federica Maria Simone (Poliba)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	May-June 2025
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (60% minimum of presence) ☐ No
Course unit contents	● Recalls of interaction between radiation and matter; ionisation and excitations; photoelectric effect; ● charge transport, diffusion, drift in electric and magnetic fields; ● charge and avalanche multiplication, first and second T ownsend coefficient, Penning effect, avalanche statistics; ● signal formation; ● ionisation chambers, proportional counters, proportional wire chambers multiple (MWPC), Micro Strip Gas Chambers, Triple GEM, Micromegas, Micro-rwell. ● Applications in high-energy physics experiments
Learning goals	By the end of the course, the student will have: - learned the basics of the operating principle of gas-gaseous detectors - acquired skills in the characteristic parameters of detectors, such as spatial and temporal resolution spatial and temporal resolution, gain, rate capability - acquired knowledge of the use of such devices in high energy physics experiments energies - learned how to search and consult scientific articles on the subject and how to present their contents
Teaching methods	Lectures with slides
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No

Prerequisites (not mandatory)	Electromagnetism, Mathematical Analysis, Modern Physics and Statistical Methods
Examination methods (in applicable)	Oral exam
Suggested readings	Provided by the lecturers
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	Semiconductor light sources for engineers
Teacher in charge (if defined)	Prof. Mariangela Gioannini and Prof. Lorenzo L. Columbo SSD: ING-INF 01 (Elettronica)
Teaching Hours	20
Number of ECTS credits allocated	2,5
Course period	June 2026
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	Principles: - Spontaneous emission, stimulated emission and light amplification in semiconductors. Semiconductor optical waveguides - Semiconductor devices based on spontaneous emission and light amplification: light emitting diodes (LEDs) and superluminescent light emitting diodes (SLDs) - Semiconductor devices based on stimulated emission: laser diodes with emission in the visible and near-infrared range - Semiconductor Quantum Cascade Lasers for Mid-infrared and THz emission - Non-linear effects in multimode semiconductor lasers: four-wave mixing; generation of optical frequency combs and optical solitons Applications: - Application of SLDs: optical coherence tomography as non-invasive technology for high resolution imaging of biological tissues - Application of laser diodes: laser diode dynamics and self-mixing interferometry for measurements of distance and velocity. Laser diodes for LIDAR. - Application of QCLs: MID-IR dual-comb spectroscopy for high-resolution, high-sensitivity broadband molecular spectroscopy. THz scattering high-resolution, high-sensitivity broadband molecular spectroscopy. THz scattering type scanning near field microscopy (s-SNOM) for subwavelength imaging
Learning goals	The aims of course are: 1). providing to students the basic principles of light-matter interaction in semiconductors and the fundamentals of semiconductor device operation for light emission. The course will present the principles of light emitting diodes, superluminescent light emitting diodes and semiconductor lasers 2) present examples of applications of these devices with focus on the most emerging applicative fields other than the conventional optical communication systems The course will therefore provide basic notions and tools to PhD students that are, or may be in future, involved in the design or application of systems employing semiconductor lasers or LEDs.
Teaching methods	-

Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	- Fundamentals of semiconductor physics and electromagnetism - Basic notions on semiconductor devices (diodes)
Examination methods (in applicable)	Oral presentation at the end of the course
Suggested readings	-
Additional information	The course is delivered every two years. Next course is scheduled in June 2026. It typically starts mid of June with 4 or 6 hours of lesson per week. The detailed calendar of the lessons will be presented at the beginning of the course and possibly discussed with the students to meet their requests and availability for attending the lessons. For additional information contact mariangela.gioannini@polito.it

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	Vacuum Technologies
Teacher in charge (if defined)	Oscar Azzolini
Teaching Hours	16 (8 lecture + 8 lab) two full days at LNL
Number of ECTS credits allocated	2
Course period	April 2025
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	Eng/Ita
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	Gas flux through channels: flux regimes; Conductance and Impedance; gas flux in viscous regime; gas flux in molecular regime; Conductance of short, long and elbow tubes; Vacuum materials: desorption, permeability, solubility, diffusion and degassing; Vacuum System Baking; Vacuum welding and brazing; Vacuum components; electrical, rotary and linear feedthroughs, Vacuuming: rotary pumps; zeolites and traps; piston pumps, membrane pumps, trochoidal pumps, scroll pumps, roots pumps, claw pumps, turbomolecular pumps, diffusion and cryogenic pumps; measuring of a vacuum chamber in low and UHV; Fundamentals of Designing - golden rules and mistakes to avoid ; Vacuum Measurement: Pirani Vacuum meters, Thermocouple Vacuum meters, Capacitance Vacuum meters, Penning Vacuum meters, Ionizing Vacuum meters, Bayard Alpert Vacuum meters, Quadrupoles Mass Analysers; real and virtual Leaks Detection. Experimental activities in Laboratory on vacuum production and leak detection.
Learning goals	Knowledge of the instruments commonly used in vacuum systems, how to solve problems that may occur, how to work towards optimal vacuums.
Teaching methods	Lectures and practical laboratory
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-

Examination methods (in applicable)	10-min PPT presentation on a topic of the course
Suggested readings	Lectures PPT
Additional information	-

Course unit English denomination	Adaptive Optics for Astronomy
Teacher in charge (if defined)	Carmelo Arcidiacono (INAF-Arcetri)
Teaching Hours	12
Number of ECTS credits allocated	1,5
Course period	March-June 2025
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	Inglese
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	Adaptive optics (AO) is an advanced technology used to improve the quality of images obtained from astronomical telescopes by correcting distortions caused by the Earth's atmosphere in real time. Without AO, the scintillation and flicker effect caused by atmospheric turbulence blurs images, significantly limiting the ability to resolve fine details of astronomical objects. AO has revolutionised modern astronomy, enabling observations impossible with conventional telescopes. The PhD course 'Astronomical Observations with Adaptive Optics' will provide an in-depth understanding of how AO works and its applications in astronomy. Students will explore the fundamental concepts and mechanisms behind these technologies and will be introduced to the tools used to measure and correct atmospheric wavefront distortions.
Learning goals	- Understanding the physical and technical principles of adaptive optics Students will gain a solid understanding of the mechanisms by which adaptive optics corrects atmospheric distortions in real time, improving the quality of astronomical images. - Designing and implementing simple adaptive optics systems At the end of the course, students will be able to design basic AO systems, understanding how to select and configure the necessary components, such as deformable mirrors and wavefront sensors. - Using adaptive optics systems to conduct astronomical observations Students will be able to apply AO principles to improve the quality of astronomical observations, exploiting technology to overcome limitations imposed by the Earth's atmosphere. - Interpret and analyse data obtained with AO systems Skills will be provided to understand and reduce data acquired through AO observations, enabling students to analyse high-resolution astronomical images and draw valid scientific conclusions. - Knowing the practical applications of AO in modern astronomy

	Students will learn to identify the different areas of astronomical research that benefit from the use of AO, such as the study of planetary surfaces, the resolution of stars in star clusters and the observation of active galactic nuclei.
Teaching methods	Lectures Guided discussions Individual or group projects
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Physics I and Physics II (Optics)
Examination methods (in applicable)	At the student's request
Suggested readings	Slides and links recommended by the lecturer
Additional information	-

Course unit English denomination	Radio and optical interferometry
Teacher in charge (if defined)	Fabrizio Massi (and others TBD)
Teaching Hours	12
Number of ECTS credits allocated	2
Course period	April-June
Course delivery method	☐ In presence ☐ Remotely ☐X Blended
Language of instruction	Italian, English is foreign students attending
Mandatory attendance	☐ Yes (% minimum of presence) ☐X No
Course unit contents	After reviewing the basic principles of interferometry, the course will deal with the astronomical applications of interferometry at optical and radio wavelengths. Observational methods, and technical and practical issues will be discussed, as well as the main differences between radio and optical astronomical interferometry. An overview of available and future observational facilities will conclude the course.
Learning goals	The main aim of the course is to provide the students with the basic knowledge needed to interpret interferometric observations and to plan their own interferometric observation
Teaching methods	Small seminars (slides), references to texts and webpages.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☐X No
Available for PhD students from other courses	☐X Yes ☐ No
Prerequisites (not mandatory)	None
Examination methods (in applicable)	The student is asked to discuss an interferometric science case found in the literature.
Suggested readings	The student will be provided with a copy of the slides and further notes.

Additional information	Set of 8 lessons, 1.5 hrs each.

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	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	Novel detectors for future experiments at collider
Teacher in charge (if defined)	Colella Domenico (Uniba)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	January/March 2025
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (50% minimum of presence) ☐ No
Course unit contents	-) Introduction to future collider and to the european strategy for the R&D activities to develop new detectors specifically designed for experiments at future colliders (2h) -) New technologies in gas detectors: muon system, inner and central tracking, photon detector, time-of-flight, rare-decays (3h) -) New technologies in solid state detectors: MAPS, CMOS planar/3D/passive, LGAD (6h) -) New technologies in PID and photon detectors: RICH, DIRC, TOF, TPC, TRD, MCP-PMT, PMT, MaPMT , HPD, MPGD, SiPM, SNSPD, TES, MKID (3h) -) New technologies in calorimetry: based on silicon, liquid noble gas, gas (1h) -) Quantum and emerging for particle detectors (1h)
Learning goals	The course aim to provide to the students the fundamental characteristics of the technologies under development for experiment to be designed to work in future colliders. Focus will be paid to the relevant aspects that are guiding the development of these technologies: radiation hardness, material budget, channel multiplicity and readout electronics bandwidth.
Teaching methods	Seminars will be given guided by educational material to be projected (slides), encouraging students interaction during the comprehension of different arguments.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites	Knowledge of radiation-material interaction

(not mandatory)	Knowledge of basic principle of particle radiation
Examination methods (in applicable)	Seminar on selected detector realization, possibly related to the student research, focusing on relevant aspects for the technology choice.
Suggested readings	Educational material (slides) used during lectures. Selected articled concerning specific arguments.
Additional information	-

Course unit English denomination	Radiation Matter Interaction
Teacher in charge (if defined)	Raffaella Radogna (Uniba)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	Spring 2025
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	- Ionizing radiations source - Heavy charged particles interaction - Electrons interaction - Gamma/X rays interaction, - photoelectric and Compton effects, pair production - Neutron interaction - Radiation and dose exposure - Methods for measuring dose - Effects on materials and detectors
Learning goals	The educational objectives of the course are: - to acquire the foundational principles of physical theories that describe the interaction of radiation with matter and its propagation; - to develop the ability to connect concepts and theories to the experimental practice of detecting ionizing radiation.
Teaching methods	Lectures supplemented by slides
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Calculus, Mechanics, Electromagnetism, Elements of Quantum Mechanics, Statistical methods

Examination methods (in applicable)	Interview/final report
Suggested readings	Slides and reference book “Techniques for Nuclear and Par:cle Physics Experiments” [Williams R. Leo]
Additional information	-

Course unit English denomination	Physics with High Energy particle detectors from photographic plates to the LHC experiments
Teacher in charge (if defined)	Simone Paoletti, Antonio Cassese (and/or Rudy Ceccarelli), INFN-FI
Teaching Hours	18
Number of ECTS credits allocated	2
Course period	April-June, with flexibility
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	In the first part of the course, we will retrace the main experiments that have contributed to the knowledge of the electroweak physics. While following the steps made to solve the main puzzles that have engaged the particle physicists from the 20th century, we will take the chance of exploring the ideas underlying the design and development of detectors. In the second part of the course we focus on the scientific goals of the LHC accelerator, how LHC works, the interaction process in proton-proton high energy collisions, specific details of the ATLAS and CMS detectors and their design differences, a brief overview of the Higgs physics at LHC and of the detector upgrades being prepared for High Luminosity LHC (HL-LHC).
Learning goals	We expect the students to learn the basic concept behind the high energy physics experiments and detectors
Teaching methods	Slides
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-
Examination methods	-

(in applicable)	
Suggested readings	slides
Additional information	-

Course unit English denomination	Solid State Detectors
Teacher in charge (if defined)	Donato Creanza (Poliba), Ilirjan Margjeka (INFN-BA)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	8 days in July or September
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	Principles of Operation of Solid-State Detectors • Manufacturing Technologies of Solid-State Devices • Solid State Detectors for Energy and Radiation Measurement • Solid State Detectors for Position Measurement • Readout Electronics • Radiation Damage • Solid State Detectors in Big Experiments
Learning goals	The course aims to illustrate the main characteristics of solid-state devices used in high-energy physics experiments
Teaching methods	Lectures supplemented by slides
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 about course topics
Suggested readings	• Lecture slides

	• Gerhard Lutz, Semiconductor Radiation Detectors, Springer • Frank Hartmann, Evolution of Silicon Sensor Technology in Particle Physics, Springer
Additional information	-

Course unit English denomination	Metodologies and techniques for the analysis of experimental data
Teacher in charge (if defined)	Alexis Pompili (Uniba)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	Spring 2025
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	Theory of Probability Probability Density Functions of random variables Distribution functions and Central Limit Theorem Hypothesis testing Parameter estimation and Goodness-of-fit Likelihood ratio and Local statistical significance of a signal. Classical confidence intervals; Global statistical significance of a new signal and Upper Limits.
Learning goals	Learners are expected to achieve, by the end of the course, a good knowledge of advanced statistics concepts and methodologies widely used in the field of Sub-nuclear and Nuclear Physics. Moreover, they are expected to have acquired a critical approach to handle observations and measurements while being aware of the statistical and systematic uncertainties and the correlations involved.
Teaching methods	Theoretical concepts are always complemented by practical applications and examples in order to establish a clear link between concepts on one hand and methodologies and application contexts on the other. Applications and examples are borrowed from the High Energy Physics field and are executed in the framework of a (PyROOT) Jupyter notebook.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites	Basic knowledge of Python and ROOT.

(not mandatory)	Main/basic concepts of statistics.
Examination methods (in applicable)	-
Suggested readings	Fully provided by the professor
Additional information	-

Course unit English denomination	Adaptive optics for astronomy
Teacher in charge (if defined)	Kalyan Kumar Radhakrishnan Santhakumari (INAF-OAPD)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	max 3750 caratteri
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (60% minimum of presence) ☐ No
Course unit contents	- Atmospheric turbulence and its effects - How to remove the effects of turbulence: Classical Adaptive Optics o Wavefront sensors ▪ Tip-Tilt Sensors ▪ Shack-Hartmann ▪ Pyramid ▪ WFS curvatures o Deformable mirrors - Limitations of Classical Adaptive Optics - Laser stars as references for wavefront sensors - Multi-conjugate adaptive optics o 'Star-Oriented' systems o 'Layer-Oriented' systems - Wavefront reconstruction o Interaction matrix o Zonal reconstruction o Modal reconstruction
Learning goals	Adaptive optics is an interdisciplinary subject that embraces contributions that ranging from real-time computing to astronomy to engineering and more. This course introduces adaptive optics in astronomy to graduate students.
Teaching methods	lectures
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 oral or written examination (to be defined later)
Suggested readings	1. ADAPTIVE OPTICS for ASTRONOMICAL TELESCOPES - JOHN W. HARDY - Oxford University Press 1998 2. Adaptive Optics for Astronomy : Principles, Performance, and Applications – Jacques M. Beckers – ANNUAL REVIEW OF ASTRONOMY AND ASTROPHYSICS Volume 31, 1993 - Ulteriori materiali di studio saranno condivisi con i partecipanti durante il corso.
Additional information	-

Course unit English denomination	Project management in science
Teacher in charge (if defined)	Maria Bergomi (INAF-OAPD)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	February-March 2025 (TBC)
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (60% minimum of presence) ☐ No
Course unit contents	After a general introduction to project management, the course will focus on its theory and application to scientific projects and research. Actual examples of project development and project management activities relating to the development of astronomical projects for observations from the ground and space will be shown and discussed. One lesson will be devoted to the preparation of a schedule using specific software (e.g. Microsoft Project). -General introduction to project management -Planning and project management tools Project Management Plan (PMP), resource allocation and FTE, Work Breakdown Structure (WBS), Work Packages (WPs), Product Breakdown Structure (PBS), Product Tree (PT), Cost Management, Risk Management, Communication Lines and Tools, Schedule and Gantt Chart -Project phases for a scientific instrument and related documentation and tools -Preparation of a schedule using dedicated software (e.g. Microsoft Project) -Brief introduction to Product Assurance
Learning goals	Learning the various techniques, methodologies and keywords of project management, to be applied to small or large scientific projects, and, more generally, to everyday scientific activities, as well as to understanding the demands placed on participants in large projects and in preparing proposals for project funding. Learning the various steps involved in the construction of an astronomical instrument.
Teaching methods	Lectures, possibly work in groups
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 examination will consist of questions related to the course topic
Suggested readings	Slides Other material will be indicated during the course
Additional information	-

Course unit English denomination	Scintillators and Silicon Photomultipliers
Teacher in charge (if defined)	Elisabetta Bissaldi, Serena Loporchio
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	Second semester (May-June 2025)
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (% minimum of presence) ☐ No
Course unit contents	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
Learning goals	This course aims to provide the student with advanced knowledge of radiation measurements and detection techniques, from classic scintillation detectors to modern Silicon Photomultiplier devices.
Teaching methods	Lectures and lab sessions
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	It requires an elementary background in radiation measurements, radiation-matter interactions and basic electronics.
Examination methods (in applicable)	Final laboratory report

Suggested readings	1. G. Knoll – “Radiation Detection and Measurement” 2. Sedra and Smith – “Microelectronic Circuits” 3. Sze - “Physics of Semiconductor Devices” 4. Recent Publications
Additional information	It is delivered in hybrid mode (both in-person and distance) including activities in the lab.