Course unit English denomination	Phenomenology of Particle Physics - Effective Field Theories and Amplitudes
SS	FIS/02 FISICA TEORICA, MODELLI E METODI MATEMATICI
Teacher in charge	Matteo Fael Pierpaolo Mastrolia
Teaching Hours	24
Number of ECTS credits allocated	3
Course period	March - June 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (50% minimum of presence) ☐ No
Course unit contents	Module: Effective Field Theory Effective Field Theories (EFTs) form the foundation of modern particle physics, providing a versatile framework to describe a broad spectrum of phenomena and calculate experimentally measurable quantities. This course covers the essential principles behind the emergence of EFTs and their consistent application in research. Special focus will be given to widely used EFTs in collider physics and their role in the search for new physics beyond the Standard Model. The course is designed for students specializing in theoretical physics, but also those involved in the CMS and Belle II experiments can benefit from it, offering a bridge between theoretical concepts and experimental exploration at the frontiers of high-energy physics. Module: Amplitudes Scattering Amplitudes and related cross sections represent the interface between Quantum Field Theory and experimental verification, and constitute the ideal "theoretical laboratory" for the study of fundamental interactions through the direct production of real particles or the indirect

	determination of their virtual effects. At the same time, Scattering Amplitudes offer an interesting window on the understanding of the formal properties of gauge theories, effective field theories (EFT) and gravity. In this course, students will familiarize with modern computational techniques for Feynman integrals, based on integration by parts identities, differential equations as well as with on-shell methods and techniques based on the spinor-helicity formalism, generalized unitarity, and integrand decomposition, reaching out to the basics concepts of intersection theory. The lectures cover applications of Feynman calculus and Scattering Amplitudes in Particle Physics and in Gravitational Waves Physics, within the General Relativity-EFT diagrammatic approach. Students' competence and abilities are finally enhanced through the participation in interdisciplinary projects that may combine Theoretical Physics, Mathematics and Computer Science.
Learning goals	The students will develop the following abilities: 1) Understand the emergence of an EFT: separation of scales, degrees of freedom, symmetries and power counting. 2) Implement an EFT as a consistent quantum field theory. 3) Model effects of new physics above the EW scale within the framework of the SM EFT. 4) Describe low-energy dynamics of hadrons containing a heavy quark using EFTs. 5) Apply the spinor-helicity formalism, on-shell and generalised unitarity; 6) Study the algebraic properties of Feynman integrals; 7) Derive and solve systems differential equations for Feynman integrals; 8) Describe higher-order effects in scattering events.
Teaching methods	Lectures are delivered at the blackboard with the aid of slides.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☐ No
Available for PhD students from other courses	☐ Yes ☐ No
Prerequisites (not mandatory)	Quantum Field Theory

Examination methods (if applicable)	Oral presentation on a topic relevant to the course or short-term research project
Suggested readings	- A. Manohar, “Introduction to Effective Field Theories,” hep-ph/1804.05863 - S. Badger, J. Henn, J. C. Plefka and S. Zoia, “Scattering Amplitudes in Quantum Field Theory,'' Lect. Notes Phys. 1021 (2024), hep-th/2306.05976
Additional information	