**PhD course in Physics, Astrophysics, and Applied Physics - Università degli Studi di Milano**
**PhD cicle 40 (2024-2025)**

**All lectures will be given in English.**

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| **Course title** | Computational, simulation and machine-learning methods in high-energy physics and beyond. Automated computational tools |
| **Teacher in charge of the course** | Stefano Carrazza |
| **List of the teachers of the course** *[surname/name; affiliation; e-mail]* | Marco Zaro, Unimi, marco.zaro@unimi.it<br>Olivier Mattelaer, Uni-Louvain, Olivier.Mattelaer@uclouvain.be (assists for the tutorials) |
| **Training objectives** | After the course, the student will know<br>- the algorithms employed to compute an arbitrary amplitude automatically.<br>- Monte-carlo techniques to efficiently perform numerical integration<br>- the concept of infra-red safety, and how to apply it to kinematic observables<br>- the basic mechanism of a parton shower, and the meaning of the Sudakov form factor<br>- how infra-red singularities arise in higher-order computations, and how to deal with them at NLO. In particular, local-subtraction methods<br>- The meaning of, and the usage of, matched/merged computations<br>- the usage of softwares like MadGraph5_aMC@NLO for the automatic computation of amplitudes and their integration |
| **Prerequisites** *[please insert details and also* ***state whether the course has advanced contents*** *suitable for students with prior knowledge of the topics or is also suitable for students without prior knowledge]* | Quantum-field theory, in particular the phenomenological aspects related to the Standard-Model. Computation of simple amplitudes and cross sections by means of Feynman diagrams. Special relativity.<br>This knowledge is required for the course |
| **Detailed course program** | Anatomy of scattering cross sections, at tree level<br>- amplitude computations using Feynman diagrams and helicity routines<br>- numerical integration techniques. From one to multi-dimensional. Multi-channeling and variable transformations<br>- How to include/exclude certain classes of Feynman diagrams, and the problems related with doing so<br>Parton-shower and multi-jet merging<br>- Collinear approximation for multi-particle amplitudes<br>- Splitting kernels, branching probabilites and the Sudakov form factor<br>- Parton-showers<br>- Merging matrix elements with different multiplicities<br>Next-to-leading order:<br>- Infrared-safety: definition and classification of observables<br>- How infra-red divergences arise in higher-order computations, and how to deal with them<br>- Local subtraction methods. FKS and dipoles<br>- (may be skipped if not enough time) Computation of one-loop diagrams<br>- Matching NLO computations with parton-showers<br>All topics will be complemented with hands-on tutorials on the students' computers |
| **Examination modalities** | Exercises, to be solved by the students |
| **Preliminary schedule** *[please indicate the weeks when the lectures will be given]* | 25-27th of June |