Advanced Standard Model

The course provides advanced knowledge of the theory of the Standard Model of elementary particle. The student will get acquainted with the properties and features of our current description of the fundamental particles and their interactions. Motivated by its theoretical limitations as well as by the current experimental observations, the students will then be exposed to the most common avenues towards extending the Standard Model and searching for new physics in high-energy experiments.

The course is divided in 3 parts (Moduli) and taught by:
Alessandro Granelli (Module 1)
Davide Pagani (Module 2)
Fabio Maltoni (Module 3)

Alessandro Granelli

Ph.D. in Astroparticle Physics, he carries out his scientific research in the field of (astro)particle physics, high energy physics and cosmology. In particular, he is interested in neutrino physics and in understanding the mechanism beneath the generation of their masses; in the matter-antimatter asymmetry of the Universe and its dynamical generation at early epochs; in dark matter and its possible particle nature. His research also focuses on interdisciplinary aspects between particle physics and astrophysics.

Davide Pagani

Since Oct 2021, he is Ricercatore at Istituto Nazionale di Fisica Nucleare (INFN). His main area of research Theoretical Physics, Particle Physics, Fundamental Interactions, High-Energy Physics, Standard Model and BSM, Precision Physics, Collider Phenomenology.

Fabio Maltoni

Full Professor at Università di Bologna since 2018, Prof. Maltoni leads a research activity in theoretical physics and phenomenology of the fundamental interactions. He has directed the Centre for Cosmology, Particle Physics and Phenomenology in 2015-2018 at UC Louvaine. His main research interests focus on QCD, the theory of strong interactions, on the simulation and study of high-energy events at colliders, and on the search for physics beyond the Standard Model through precision measurements of the properties of the Higgs boson and the top quark. He is member of the Particle Data Group and of the MadGraph collaboration.

Module 1: Neutrino physics

- Neutrinos in the Standard Model.
- Neutrino oscillations in vacuum and in matter.
- Current status and open questions for the future.
- Nature and masses of neutrinos: Majorana and Dirac particles.
- Origin of neutrino masses beyond the Standard Model.
- The baryon asymmetry and leptogenesis.
- The problem of flavour in the lepton sector.
- Neutrinos in the Universe. Brief overview of dark matter.

Module 2: Precision SM physics

- Lagrangian of the SM.
- Custodial Symmetry and the rho parameter.
- Linear and non-linear EW symmetry breaking.
- EW chiral Lagrangian.
- Unitarity and perturbativity of the SM.
- Higgs mass bounds: unitarity, triviality and stability.
- EW precision-observables (EWPO) and renormalisation schemes.
- Higgs phenomenology: decays and production.
- Top-quark phenomenology: decays and single and pair production.

Module 3: Effective field theories

- Introduction. Motivation and basic concepts. Simple examples.
- Machinery and Tools: matching, power counting, equations of motion, running, toy models.
- Applications: Fermi Theory, Euler-Heinsenberg, FCNC, NRQED.
- The Standard Model as an Effective Field Theory: Linear and non-linear extensions.
- Phenomenology and constraints from precision experiments.
- SMEFT at the LHC and future colliders.

Exam

1. One part on an individual project
2. One part on the course

Details will be given in the first lecture.