The Standard Model (L24)

Professor M. Ubiali

The Standard Model

The Standard Model of particle physics represents the most successful application of quantum field theory (QFT) to date, accurately describing all current experimental measurements of the strong, weak, and electromagnetic interactions. This course demonstrates how this QFT, defined by the gauge group $SU(3) \times SU(2) \times U(1)$ and comprising fermion fields for leptons and quarks, is realised in nature.

Intended to complement the Advanced QFT course, it bridges foundational field theory with the phenomenological reality of modern particle physics, including glimpses into physics beyond the Standard Model.

The course will cover a selection of topics including:

- Symmetries and Particle Content: Local (gauge) and global symmetries; elementary particle spectrum (spin-1/2 leptons and quarks, spin-1 gauge bosons, and the spin-0 Higgs boson); investigation of discrete symmetries (P, C, and T) and parity violation in weak interactions.
- The Electroweak Sector and the Higgs Mechanism: Spontaneous symmetry breaking and Goldstone's theorem; the Higgs mechanism and the breaking of $SU(2) \times U(1)$ gauge symmetry; electroweak precision tests.
- Flavour Physics and CP Violation: The generation structure of quarks and leptons; the CKM matrix; mechanisms and consequences of CP violation in the three-generation electroweak sector; neutrino masses and oscillations as windows to new physics.
- Electroweak Phenomenology: Connecting matrix elements to observable quantities (cross sections and decay rates); perturbative computations for scattering and decay processes.
- Quantum Chromodynamics (QCD): The non-abelian $SU(3)$ gauge theory of strong interactions; colour confinement and hadronisation at low energies; asymptotic freedom and high-energy perturbation theory; electron-positron annihilation into hadrons.
- Advanced Topics (Time Permitting): Deep Inelastic Scattering (DIS), the Feynman parton model, the QCD-improved parton model, and QCD collinear factorisation; the Standard Model treated as an effective field theory (EFT) to accommodate potential beyond-the-Standard-Model (BSM) effects.

Prerequisites

It is necessary to have attended the Quantum Field Theory and the Symmetries, Fields and Particles courses, or to be familiar with the material covered in them. It would be advantageous to attend the Advanced QFT course during the same term as this course, or to study renormalisation and non-abelian gauge fixing.

Literature

1. M. E. Peskin and D. V. Schroeder, *An Introduction to Quantum Field Theory.* Addison-Wesley, 1995.

2. T-P. Cheng and L-F. Li, *Gauge Theory of Elementary Particle Physics.* Oxford University Press, 1984.

3. M. D. Schwartz, *Quantum Field Theory and the Standard Model.* Cambridge University Press, 2nd edition, 2020.

4. J. F. Donoghue, E. Golowich and B. R. Holstein, *Dynamics of the Standard Model*, Cambridge University Press, 2014.

5. F. Halzen and A. D. Martin, *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, Wiley, 1984.

6. C. M. Becchi, G. Ridolfi, *An Introduction to Relativistic Processes and the Standard Model of Electroweak Interactions*, Springer, 2016.

Additional support

Four examples sheets will be provided and four associated examples classes will be given. There will be a one-hour revision class in the Easter Term.