Gauge Theories of the Standard Model

Professors:
Domènec Espriu (50%, coordinador)
Jorge Casalderrey (25%)
Federico Mescia (25%)

Time Schedule: Mon, Tue, Wed: 11:50 – 13:10

According to our current state of knowledge, all fundamental interactions are based on the gauge principle.

Allow us to describe massless particles of spin one (photons, for instance) in a Lorentz invariant manner.

- Unitarity
- Renormalizability
- Predictivity

The Higgs mechanism is intimately related to gauge symmetries.
How to give mass to the “photon” without losing all the nice properties of gauge theories

QED, QCD (strong interactions) and Weak Interactions are all examples of gauge theories.

Programme:

- 3 blocks:

  Introduction to gauge interactions and their quantization

  Strong interactions (QCD)

  Electroweak theory

- The basic objective:

  Study of gauge interactions beyond tree level and the associated phenomenology

Contents:

This course deals with the subtleties related to the quantization of non-abelian theories and the basics of QCD and the Electroweak Theory (EWT).

Formal developments are presented in the path integral formalism and applied both to QCD and the EWT.

Diagrammatic techniques are used for the more phenomenological parts.

In the study of QCD the emphasis is on symmetries and their realization.

Deep inelastic scattering is not studied here (see 'Elementary Particle Physics') but the renormalization of the theory, including renormalization ambiguities, the OPE, decoupling and the renormalization group are treated.

The EWT is thoroughly studied, taking off from where it was left in 'Elementary Particle Theory', including radiative corrections. Some more advanced topics such as effective lagrangians for weak interactions and precision observables in the EWT are covered.

Syllabus:

PART I

I Introduction

1.- Euclidean and Minkowski conventions.
2.- Summary of path-integral techniques for a scalar theory.
3.- The effective action and functional methods.
4.- The phenomenon of spontaneous symmetry breaking.
5.- Classical gauge invariance in abelian and non-abelian theories.

II Classical solutions in gauge theories

1.- The 2d O(3) sigma model.
2.- The 't Hooft-Polyakov monopole.
3.- Instantons.
4.- Zero-modes and chiral symmetry breaking.

III Introduction to QCD

1.- Why QCD?
2.- The classical lagrangian of QCD
3.- Global symmetries of QCD and their realization.
4.- The U(1)_A anomaly.
5.- The theta vacuum.
6.- Anomaly cancellation.

IV Quantization of gauge theories

1.- Covariant quantization: Faddeev-Popov formalism in QED and Yang-Mills.
2.- Ghosts in Yang-Mills. Feynman rules. Unitarity.
3.- BRST symmetry.
4.- Ward and Slavnov-Taylor identities.
5.- Spontaneous symmetry breaking and renormalizability.
6.- R-gauges and modified Slavnov-Taylor identities.

Syllabus:

PART II

V Radiative corrections in gauge theories

1.- Divergent structure of gauge theories.
2.- Renormalization and counter-terms in QCD.
3.- The meaning of renormalization.
4.- Calculation of the beta function in QCD.
5.- The renormalization group. Fixed points.
6.- The R-observable.
7.- Renormalization ambiguities and the renormalization group.
8.- Decoupling of heavy quarks.

VI The limits of perturbation theory

1.- Confinement
2.- Infrared divergences. Inclusive and Exclusive processes.
3.- The Operator Product Expansion (OPE).
4.- Power corrections to the R observable.

Syllabus:

PART III

VII Gauge structure of the electroweak theory
1.- Summary of known results.
2.- Gauges and gauge fixing. Physical states.
3.- Mass generation and spontaneous symmetry breaking.
4.- Fermion masses.
5.- The CKM matrix.
6.- Semileptonic decays.

VIII The Electroweak Theory beyond tree level
1.- FCNC and the GIM mechanism.
2.- CP symmetry and CP violation in kaons and other neutral systems.
3.- The Gilman-Wise effective lagrangian.

IX Radiative corrections in the Electroweak theory
1.- Effective couplings
2.- The on-shell scheme.
3.- Precision observables.

Language: English

Evaluation:

- 60% Homework
- 40% Exam at the end of the course