The Standard Model of particle physics and beyond

A. Vicente[a]

[a] Instituto de Física Corpuscular (CSIC-Universitat de València),
Apdo. 22085, E-46071 Valencia, Spain

Abstract

In this course we will review the foundations of the Standard Model (SM) of particle physics. After a brief description of the first phenomenological theories for the weak interactions we will study the two central ingredients of the SM: gauge invariance and spontaneous symmetry breaking. We will then show how these ingredients are combined to construct the SM and derive some its fundamental predictions and consequences. Finally, in the last lecture we will discuss the most relevant SM drawbacks and mention some of the most popular extensions that have been put forward to solve them.

Notes of the course given at University of Milano Biccoca, Milano (Italy)
ISAPP 2016 "Physics and astrophysics of cosmic rays in space"
September 12th-14th, 2016.

Contents

1 Introduction

The making of the Standard Model (SM) was the result of combining crucial experimental results with clever theoretical ideas. In this course we will begin with the first steps given towards the establishment of a consistent theory for the weak interactions, paying attention to the most relevant experimental results that guided the efforts and the fundamental theoretical breakthroughs that came with them. In particular, we will have a detailed look at gauge theories with spontaneous symmetry breaking. With these ingredients, we will use the second lecture to build the SM and to discuss its most important features and predictions. Finally, and despite its enormous success in explaining experimental data, the main SM problems will be the subject of our last lecture, where some of the possible solutions will also be introduced.

What is this course about?

I should emphasize several details of this course, of interest to the reader:

- Even though the crucial experimental discoveries will be mentioned, the discussion will be completely focused on the theoretical developments.
- In this course I will concentrate on the electroweak interactions, leaving the discussion of the strong interactions to other courses.
- A basic training in Quantum Field Theory (QFT) will be assumed.
- Some exercises will be proposed after each lecture. These will be directly related with the content of the lecture.

Bibliography

There are many good books and reviews that introduce the SM in detail from many different perspectives. In the making of these notes I have been particularly inspired by the following texts, which had an impact on them:

Books

Gauge theory of elementary particle physics, Ta-Pei Cheng & Ling-Fong Li [1]
Gauge theories of the strong, weak and electromagnetic interactions, Chris Quigg [2]
Gauge theories in particle physics. A practical introduction. Volume 2, Ian J. R. Aitchison & Anthony J. G. Hey [3]

Articles

Standard Model: an introduction, Sergio F. Novaes [4]
The need for the Higgs boson in the Standard Model, Jorge Romão [5]
The making of the Standard Model, Steven Weinberg [6]