Introduction to on-shell scattering amplitude

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Advanced Quantum Field Theory

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Course Description

The computation of observables in relativistic quantum theories is based on the knowledge of the so-called scattering amplitude that encodes all the informations about the interactions. Traditionally, scattering amplitudes have been computed introducing quantum fields and implementing all the machinery of standard Quantum Field Theory. Despite being extremely powerful, some complications as the gauge redundancy in the description of massless states with spin higher or equal to 1, or the freedom to perform fields redefinitions that sometimes obscure the physics, motivate searching for alternatives and complementary approaches. Our purpose in this mini-course is to introduce on-shell scattering amplitudes techniques, in which no quantum fields are ever introduced and the aforementioned difficulties are absent. We will discuss how scattering amplitudes can be constructed simply by imposing Lorentz symmetry, treating both the cases of massless and massive particles. The final part of the course will be devoted to a discussion of possible applications in the context of Effective Field Theories.

Course Structure

The course will consist of a total of 16 lecture hours, 4 per week. It will be part of the "Advanced Quantum Field Theory" course offered to master and PhD students. We will develop the following topics:

Preliminaries: Review of the unitary representations of the Poincarè group, with emphasis on the little group of massless and massive particles [4 hours];

Part 1: On-shell amplitudes for massless states: construction from the little group covariance, spin-helicity variables, discussion of some important results (construction of higher point amplitudes from three-points ones, uniqueness of Yang-Mills and General Relativity) [4 hours];

Part 2: On-shell amplitudes for massive states: differences and analogies with the massless case, some important results [4 hours];

Part 3: Applications to Effective Field Theories [4 hours].

Required Materials

The course will be based on the following references:

- *A Course in Amplitudes*, Tomasz R. Taylor, arXiv:1703.05670;
- *Scattering Amplitudes*, Henriette Elvang and Yu-tin Huang, arXiv:1308.1697 (see also the book published by Cambridge University Press);
- *Scattering Amplitudes For All Masses and Spins*, Nima Arkani-Hamed, Tzu-Chen Huang and Yu-tin Huang, arXiv:1709.04891

Prerequisites

Prerequisites: Quantum Field Theory. The topics directly relevant for the mini-course will be briefly reviewed during the lectures.