Gauge Fields and the Standard Model

Lecturer: Andrei Arbuzov

8th semester

Lectures: 32 hours

Course abstract

The course is an introduction to the theory of gauge fields and the standard model of charged particle interaction. The gauge invariance principles are one of the bases of developing physical theories describing the microworld. Quantum electrodynamics, quantum chromodynamics, and the theory of electroweak interactions are the main example of these theories.

The standard model of elementary particle physics describes perfectly a huge diversity of observations and experimental data. The model includes also the Glashow – Salam – Weinberg theory of electroweak interactions and quantum chromodynamics. It is believed that the gravitational interaction should also be described by the gauge field theory. The basic principle of developing the model consists in using symmetries as nature's fundamental properties. The interactions between particles are introduced in the standard model by considering the gauge symmetries in corresponding sectors. The symmetries in the models describing the Abelian and non-Abelian gauge fields lead to nontrivial topological solutions of the field equations: monopoles and instantons. Also discussed in the course are symmetry violation mechanisms – in particular, the Higgs model. Considered are the properties of the electroweak vector bosons and the Higgs scalar particle. Discussed is a program of modern experimental research in high energy physics. Considered is the phenomenology of particle interaction processes at the colliders, including the Large Hadron Collider and International Linear Collider.

Prerequisites

The courses "Introduction to the Quantum Field Theory" and "Elementary Particle Physics."

Lecture 1. Symmetry in the laws of physics. Global and local symmetries. Mathematical description of group symmetries. Classification of Lie algebras.

Lecture 2. Abelian and non-abelian gauge groups. Gauge symmetries on the example of Quantum electrodynamics. Gauge bosons.

Lecture 3. Basic principles of building the models describing interactions of particles. Phenomenology of the physics of elementary particles as a research object.

Lecture 4. Symmetries in the theory of strong interactions and spectroscopy of hadrons. Gauge theory of strong interactions – quantum chromodynamics.

Lecture 5. Main features of QCD. Self-action of the non-abelian fields. Asymptotic freedom. Confinement. Breakdown of the chiral symmetry.

Lecture 6. The structure of weak currents. Lepton and semi-lepton decays. Fermi theory of weak interactions. Unitary limit and non renormalizability of the theory.

Lecture 7. Weak interactions and their features. CP-violation in weak interactions. The idea of unification of weak and electromagnetic interactions in the gauge field theory framework

Lecture 8. Spontaneous and dynamical symmetry breaking. Goldstone theorem. Mechanism of Higgs. Symmetry of the Higgs sector of the standard model.

Lecture 9. Mechanism of spontaneous symmetry breaking between electromagnetic and weak interactions.

Lecture 10. Derivation of the lagrangian of the standard model of electroweak interactions and discussion of its features. Hypothesis of Grand unification of all kinds of interactions.

Lecture 11. Charged and neutral currents, relation between coupling constants. Properties of the electroweak gauge bosons and comparison with the experiment.

Lecture 12. Properties of the Higgs scalar and the program of its study at LHC and ILC.

Lecture 13. Main methods of precision verification of the standard model and search of new physical phenomena in interactions of particles. Radiative corrections.

Lecture 14. Methods of computing radiational correction in KHD, KED and weak sector of standard model. Theorem of factorization in KHD and KED.

Lecture 15. Renormalization in the standard model. Chiral anomalies.

Lecture 16. Possible expansions of the minimal standard model. Phenomenology of supersymmetric models.