Elementary Particle Physics

Lecturer: Mikhail Sapozhnikov
Specialty course
8th semester

12 lectures and 5 seminars

Course aims

Studying the main concepts that are necessary for taking advanced elementary particle physics courses like quantum chromodynamics and electroweak interaction theory. Discussing classic experiments in elementary particle physics. Discussing connection between cosmology and elementary particle physics.

Course contents

- Lecture 1. Current and probability density. Klein – Gordon equation. Dirac equation. Dirac matrices. Physical interpretation of the Dirac equation solutions: antiparticles, helicity, spin operator. Dirac spinor structure.
- Lecture 2. Gauge invariance. Local and global gauge invariance. Examples of the global and local gauge symmetry. QCD lagrangian. Color charge. Gluon discovery. Color wave functions of gluons. Asymptotic freedom.
- Lecture 3. Confinement. Color strings. Color singlet hadrons. Chiral symmetry. Weil equations. Relativistic particle helicity. Chiral projection operators. Bilinear combinations of gamma-matrices. Spontaneous violation of chiral symmetry. Goldstone theorem. Physical sense of the vacuum condensate.
- Lecture 4. Quark vacuum condensate. Particle mass spectrum and quark condensate parameters. Gluon condensate. Instantons. Instantons and emergence of the quark condensate. Contribution of different condensates to the proton mass. Chiral symmetry recovery.
- Lecture 5. Quark condensate and meson mixing. Gell-Mann – Okubo square-law mass formula. Eta meson problem. Vacuum and scalar fields in the Universe. Casimir effect. Cosmologic constant problem. Vacuum energy. Standard cosmology problem (homogeneity and precise adjustment of the expansion parameters). Inflation model of the Universe.
- Lecture 6. Scattering on a composite object. Formfactor. Elastic ep-scattering formfactors. Scattering on point objects; differential and full scattering cross-section. Transferred pulse in scattering and annihilation reactions. Deeply inelastic scattering of leptons: kinematical variables. Scaling. Parton model.
- Lecture 7. Parton spin and charges. Parton distributions of valence and sea quarks. Share of the proton pulse carried by gluons. Asymmetry of the sea quarks, and u- and d-quarks. Spin crisis. Annihilation $e^+e^- \rightarrow$ hadrons. Experimental determination of the quark color number.
- Lecture 8. Weak interaction. Main processes. Weak charges. Beta-decay. Fermi and Gamow – Teller transitions. Curie curve. Experiments on measuring the neutrino mass in tritium beta-decay. Lobashov experiments and neutrino cloud hypothesis. Inverted beta-decay. Neutrino – nucleon interaction cross-section. Wu, Ledermann, and Telegdi experiments. Parity violation in the lambda decay.
- Lecture 9. V–A structure of the weak interaction. Experiments on proving the V–A mode of the weak interaction. Charged currents structure. Neutral currents and their structure. Universality of the weak interaction according to Cabibbo. Kobayashi – Maskawa mixing matrix and CP-violation.
- Lecture 10. Fundamentals of the standard electroweak model. Weak isospin and hypercharge. Electroweak interaction. Relation between the weak and electromagnetic currents. Renormalization concept. Lamb's shift and the electron anomalous moment.
- Lecture 11. Local gauge invariance for SU(2)xU(1) groups. Spontaneous symmetry violation. Higgs mechanism. Fermion masses in the Standard model.

- Lecture 12. Neutrino oscillations. Results of the experiments on studying the solar, atmospheric, and accelerator neutrinooscillations.