Riga Technical University

University of Latvia

RTU/LU Course

General data

Code	HEP001
Course title	Particle Physics Theory
Course status in the programme	Obligatory
Course level	Doctoral Studies
Course type	Academic
Field of study	High-Energy Physics
Responsible instructor	Yuri Dokshitzer
Volume of the course: parts and credits points	1 part, 8 Credit Points
Language of instruction	EN
Possibility of distance learning	Not planned
Abstract	This course explains how do special relativity and quantum mechanics combine to give birth to the relativistic quantum field theory (QFT). The students will understand the origin of antiparticles, of the running coupling, learn relativistic quantum scattering theory and, specifically, its applications to high-energy interactions. The concept of gauge theories is introduced, and Quantum Electrodynamics (QED) is dealt with in detail as the first example of a successful gauge theory based on the abelian gauge group U(1) of phase transformations. A generalization to the non-abelian gauge group SU(2) forms the base for constructing the weak interaction sector of the Electroweak theory. Spontaneous symmetry breaking gives masses to all intermediate weak bosons (Z,W,H) as well as to fundamental matter fields (leptons, quarks). Non-abelian "colour" symmetry SU(3) leads to Quantum Chromodynamics (QCD), which complements the Standard Model. The physical origin of Asymptotic Freedom is explained. An emphasis is put on multiparticle production in energetic lepton-hadron and hadron-hadron collisions which is due to quark-gluon cascades, and a manifestation of quarks and gluons as hadron jets in the final state of hard processes.
Goals and objectives of the course in terms of competences and skills	To learn three complementary ways of constructing QFTs: canonical quantization, functional integral and the Feynman diagram approach. To understand the nature of causality, unitarity, crossing symmetry as key properties of a relativistic QFT, as well as the concept of renormalization. Become familiar with Feynman rules and perturbation techniques. To understand the principle of gauge theories and peculiarities of the gauge groups. To know the basic elements of QED, QCD and Electroweak Theory. • To be able to estimate basic lepton-hadron and hadron-hadron interaction cross sections, and the structure of the multi-hadron final states.
Structure and tasks of independent studies	The independent studies will take the form of further reading and some homework throughout the course. The students will be given problems of increasing difficulty to attempt at home with the aim of them being able to complete at least one problem in a set and attempt the rest. The further reading will be given in the form of recommendations of various sources of information, including textbooks, and material available online.
Recommended literature	George Sterman, "An Introduction to Quantum Field Theory", Cambridge University Press, 1993 M. E. Peskin, D. V. Schroeder, "An Introduction to Quantum Field Theory", Addison-Wesley, 1995 L. H. Ryder, "Quantum Field Theory". Cambridge, 1996 M. Böhm, A. Denner, H. Joos, "Gauge Theories of the Strong and Electroweak Interaction", Springer, 2001 J.C. Collins: "Renormalization", Cambridge University Press, 1986 Yu. L. Dokshitzer. V. A. Khoze, A. H. Mueller and S. I. Troyn, "Basics of Perturbative QCD", Ed. Frontieres, 1991
Course prerequisites	Relativistic classical mechanics, Non-relativistic quantum mechanics, Functional analysis
Courses acquired before	Introduction to particle physics, Mathematics for particle physics

Course contents

Content	Full- and part-time intramural studies		Part time extramural studies	
	Contact Hours	Indep. work	Contact Hours	Indep. work
Quantum field theory and perturbation expansion. General properties of QFT scattering amplitudes: causality, unitarity, crossing	24	30	-	-
Abelian gauge theory and Quantum Electrodynamics	12	30	-	-
Non-abelian gauge theory and electroweak theory. Spontaneous symmetry breaking.	20	35	-	-
Quantum Chromodynamics. Colour and Asymptotic Freedom	14	35	-	-

Hard processes. Quarks and gluons as “partons”. Parton Evolution Equations and jets.	30	90	-	-
Total:	100	220	-	-

Learning outcomes and assessment

Learning outcomes	Assessment methods
Students understand the origin of QFTs and can follows the logic of their construction. Students are familiar with Lie groups and can apply the knowledge of the key objects like group generators, fundamental and adjoint representations, group structure constants to perform simple calculations.	Examination: homework problems; oral examination. Assessment: the student will be able to attempt the homework problems and will be able to clearly explain orally the concepts learned.
Students know the basics of relativistic scatterring theory, invariant amplitudes and their properties related to unitarity, crossing symmetry and causality. They can describe the structure of the Standard Model and understand the spontaneous symmetry breaking as the mechanism that supplies masses to elementary particles.	Examination: homework problems; oral examination. Assessment: the student will be able to attempt the homework problems and will be able to clearly explain orally the concepts learned.
Students know the basics of perturbation theory and can perform quantitative analysis of multiplicities and distributions of QCD partons - quarks and gluons - that form jets in hard collisions involving hadrons.	Examination: homework problems; oral examination. Assessment: the student will be able to attempt the homework problems and will be able to clearly explain orally the concepts learned.

Evaluation criteria of study results

Criterion	%
Homework problem sets	60
Oral examination	40
Total:	

Course planning

Part	Semester			CP	ECTS	Hours per Week			Tests			Tests (free choice)		
	Autumn	Spring	Summer			Lectures	Practical	Lab.	Test	Exam	Work	Test	Exam	Work
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