DFC.112.HEP Non-abelian gauge theories

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Department of Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Physics
1.5. Course of study	Master of Science
1.6. Study program	High Energy Physics (in English)
1.7. Study mode	Full-time study

2. Course unit

2.1. Course unit title	Non-abelian gauge theories							
2.2. Teacher				Prof. Dr. Virgil Baran				
2.3. Tutorials/Practicals instructor(s)				Lecturer dr. Roxana Zus				
2.4. Year of study	II	2.5. Semester	2	2.6. Type of evaluation	E	2.7. Type of course unit	Content[1)]	**DC**
							Type[2)]	**DFC**

[1)] fundamental (DF), specialized (DS); complementary (DC)
[2)] compulsory (DI), elective (DO), noncompulsory disciplines (DFC)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	**4**	distribution: Lecture	**2**	Practicals/Tutorials	**2**
3.2. Total hours per semester	**56**	Lecture	**28**	Practicals/Tutorials	**28**

Distribution of estimated time for study	**hours**
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	**15**
3.2.2. Research in library, study of electronic resources, field research	**15**
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	**10**
3.2.4. Preparation for exam	**4**
3.2.5. Other activities	**0**

3.3. Total hours of individual study	**44**
3.4. Total hours per semester	**100**
3.5. ECTS	**4**

4. Prerequisites (if necessary)

4.1. curriculum	Quantum field theory, Electrodynamics, Theory of relativity, Nuclear physics
4.2. competences	Knowledge about: mechanics, algebra, quantum mechanics

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Video projector
5.2. for practicals/tutorials	

6. Specific competences acquired

Professional competences	• Identify and proper use of the main physical laws and principles in a given context: the use of the concepts of the standard model • Solving problems of physics under given conditions • Use of the physical principles and laws for solving theoretical or practical problems with qualified tutoring • Rigorous knowledge of quantum field theory, concepts, notions and problems in the area of theoretical particle physics and their interactions • Ability to use this knowledge in interpretation of experimental result and understand experiments at CERN; acquire the appropriate understanding of studied fundamental mechanisms
Transversal competences	• Efficient use of sources of information and communication resources and training assistance in a foreign language • Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Understanding the foundations of structure of the matter: fundamental constituents and interactions between them; Understanding the structure of unified theory of interactions
7.2. Specific objectives	Acquire the skills to describe and calculate the physical properties of elementary particles and their interactions. Understanding the non-perturbative features of symmetry breaking in different situations.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations/ hours
Quantization of the fundamental fields, elementary particles, commutation relations, spin-statistics theorem.	Systematic exposition - lecture. Examples	4 hours
Local gauge invariance and interaction. Spontaneous breaking of symmetries. Goldstone model. Higgs mechanism.	Systematic exposition - lecture. Examples	4 hours
Interacting quantum fields. Feynman diagrams. Fundamentals of renormalization.	Systematic exposition - lecture. Examples	4 hours
Non-abelian gauge theories: formulation and quantization	Systematic exposition - lecture. Examples	6 hours
Renormalization of non-abelian gauge theories	Systematic exposition - lecture. Examples	6 hours
Anomalies	Systematic exposition - lecture. Examples	4 hours

Bibliography:

1. M. Maggiore, *A modern introduction to Quantum Field Theory*, Oxford University Press, 2005.
2. M.E. Peskin, D.V. Schroeder *An Introduction to Quantum Field Theory*, Advanced Book Program, Addison-Wesley Publishing Company, 1995.
3. S. Weinberg, *The quantum theory of fields*, Vol. I and Vol. II Cambridge University Press, 2005.
4. F. Halzen, A. Martin, Quarks and Leptons, *An Introductory course in modern particle physics*

John Wiley & Sons Inc., 1984		
8.2. Tutorials [main themes]	Teaching and learning techniques	Observations/hours
Path integrals in quantum mechanics and quantum field theory	Problem solving	4 hours
Yang-Mills fields: path integral quantization	Problem solving	6 hours
Non-abelian gauge theories: exercises and applications	Problem solving	6 hours
Renormalization of non-abelian gauge theories: exercises and applications	Problem solving	8 hours
Anomalies: exercises and applications	Problem solving	4 hours

Bibliography:

1. Voja Radovanovich, *Problem book in quantum field theory*, Springer, 2005
2. M.E. Peskin, D.V. Schroeder *An Introduction to Quantum Field Theory*, Advanced Book Program, Addison-Wesley Publishing Company, 1995.
3. S. Weinberg, *The quantum theory of fields*, Vol. I and Vol. II Cambridge University Press, 2005.
4. M. Maggiore, *A modern introduction to Quantum Field Theory*, Oxford University Press, 2005.
5. W. Greiner, B. Müller, *Gauge Theory of Weak Interactions*, Springer, 2009
6. W. Greiner, S. Schramm , E. Stein, *Quantum Chromodynamics*, Springer, 2007

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical competences, which are fundamental for a Master student in the field of modern physics, corresponding to national and international standards. The contents is in line with the requirement of the main employers of research institutes and universities.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight in final mark
10.4. Lecture	- Clarity and coherence of exposition - Correct use of the methods/ physical models - The ability to give specific examples	Written test and oral examination	60%
10.5.1. Tutorials	- Ability to use specific problem solving methods	Homeworks	40%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) At least 50% of exam score and of homeworks.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
10.10.2024	Prof. dr. Virgil Baran	Lecturer dr. Roxana Zus

Date of approval

Head of Department

Lecturer dr. Roxana Zus