D0.204.1.HEP Particle physics at the LHC

1. Study program

1.1. University	„Alexandru Ioan Cuza" University of Iasi, University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Department of Theoretical Physics, Mathematics, Optics, Plasma and Lasers (Bucharest), Department of Physics (Iasi)
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	Particle physics at the LHC							
2.2. Teacher				Daniel Radu				
2.3. Tutorials/Practicals instructor(s)				Daniel Radu				
2.4. Year of study	II	2.5. Semester	1	2.6. Type of evaluation	E	2.7. Type of course unit	Content[1)]	**DS**
							Type[2)]	**DO**

[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	**30**
3.2.2. Research in library, study of electronic resources, field research	**30**
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	**32**
3.2.4. Preparation for exam	**4**
3.2.5. Other activities	**0**

3.3. Total hours of individual study	**96**
3.4. Total hours per semester	**150**
3.5. ECTS	**6**

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, Electrodynamics, Theory of relativity, Standandard Model, Dectors
4.2. competences	Knowledge about: algebra, quantum mechanics, electrodynamics, standarm model of elementary particles, detectors

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	To supply good knowledge on specific elements related to the state of the art in elementary particle physics at CERN, both theoretically and especially experimentally and phenomenologically. Presentation of the current situation at the LHC regarding the "interaction" between theory and experiment and to teach the maximum amount of physics, with the minimum level of maths.
7.2. Specific objectives	▪ Application of knowledge to practical situations; ▪ Ability in extracting information from a large variety of sources. The main feature of this course is that it gives a serious explanation of the practical side of the subject at an accessible level for undergraduates. This will provide students with some real understanding of these subjects and equip them to appreciate the many excellent graduate-level textbooks in these fields and to follow published papers. The core of the course covers the theory and experiments that underpin the Standard Model. ▪ Upon successful completion of this discipline, students will be able to describe and explain physical phenomena and processes related to the discipline; ▪ Upon successful completion of this discipline, students will be able to analyze physical phenomena and processes related to the discipline, as well as calculate values of physical quantities involved in both discipline-related and boundary/interdisciplinary physical phenomena and processes.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations/ hours
Units. Particles and forces. Accelerators, colliders and detectors	Systematic exposition - lecture. Examples	2 hours
Discrete symmetries. J^{PC} of hadrons. Addition of angular momentum. Spatial rotations. Lorentz invariance. Rapidity.	Systematic exposition - lecture. Examples	2 hours

Transitions and observables. Decay rate. Cross section. Luminosity and event rates.	Systematic exposition - lecture. Examples	2 hours
Accelerators. Radiofrequency acceleration. Beam optics. LHC dipole magnets. Colliders and fixed-target accelerators. p-anti_p colliders.	Systematic exposition - lecture. Examples	2 hours
Particle detectors. Particle interaction with matter. Signal generation. Photon detection. Detectors for charged-particle tracks.	Systematic exposition - lecture. Examples	2 hours
Detectors for particle jets. Detectors for particle identification. LHC triggers. Neutrino detectors.	Systematic exposition - lecture. Examples	2 hours
The quark model of hadrons. Heavy quarks. Exotic hadrons.	Systematic exposition - lecture. Examples	2 hours
Elements of quantum mechanics. Spinors. One-particle states. Klein-Gordon and Dirac equations. Gauge symmetry.	Systematic exposition - lecture. Examples	2 hours
Weak interactions of leptons. Weak interaction including quarks. Introduction to electroweak unification. The Standard Model, how good is it?	Systematic exposition - lecture. Examples	2 hours
Experimental tests of electroweak theory. Neutrinos. Charged and neutral currents. Physics at e^+e^- colliders. W and Z physics at hadron colliders. Top-quark physics.	Systematic exposition - lecture. Examples	2 hours
Quark-parton model. Neutrino interactions. Charged-lepton probes. QCD introduction. Hadron-hadron collisions.	Systematic exposition - lecture. Examples	2 hours
Oscillations and CP violation in meson systems. LHCb measurements	Systematic exposition - lecture. Examples	2 hours
Neutrino oscillations. Laboratory confirmation of atmospheric neutrino oscillation. Solar neutrinos. MSW effect.	Systematic exposition - lecture. Examples	2 hours
The Higgs boson. Spontaneous symmetry breaking. Higgs mechanism. Higgs discovery. LHC and SM physics. Experimental searches for BSM physics at the LHC.	Systematic exposition - lecture. Examples	2 hours

Bibliography:

1. S. Weinberg, *The quantum theory of fields*, Vol. I and Vol. II Cambridge University Press, 2005.
2. G. Barr, R. Devenish, R, Walczak & T. Weidberg, *Particle Physics in the LHC Era*, Oxford University Press, 2016.
3. F. Halzen, A. Martin, *Quarks and Leptons, An introductory course in modern particle physics* John Wiley & Sons Inc., 1984
4. R.P. Feynman, R.B. Leighton and M. Sands, Feynman Lectures on Physics, Vol. II, Addison-Wesley, 1965.

8.2. Tutorials [main themes]	Teaching and learning techniques	Observations/hours
Applications of the topics presented in the lecture.	Problem solving. Presentation	28 hours

Bibliography:

1. G. Barr, R. Devenish, R, Walczak & T. Weidberg, *Particle Physics in the LHC Era*, Oxford

University Press, 2016.

2. F. Halzen, A. Martin, *Quarks and Leptons, An introductory course in modern particle physics* John Wiley & Sons Inc., 1984

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	- coherence and clarity of exposition - correct use of equations/mathematical methods/physical models and theories - ability to indicate/analyse specific examples	Oral examination	40%
10.5.1. Tutorials	- ability to use specific problem solving methods - ability to analyse the results	Homeworks/Presentations	60%
10.6. Minimal requirements for passing the exam			
Attendance of at least 50% for the lectures and at least 70% for the tutorials. **Correct solutions to the indicated subjects for obtaining the grade 5 (10 points scale) from all activities, part of the continuous evaluation.** **Correct solutions to the indicated subjects for obtaining the grade 5 (10 points scale) within the final exam.**			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
4.10.2024	Daniel Radu	Daniel Radu

Date of approval

Head of Department
Lect.dr. Roxana Zus