DI.206.HEP Monte Carlo simulations in particle physics II (in HEP)

1. Study program

1.1. University	University of Bucharest, West University of Timișoara,
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	Monte Carlo simulations in particle physics II (in HEP)							
2.2. Teacher				Michele Renda, Călin Alexa				
2.3. Tutorials/Practicals instructor(s)				Michele Renda, Călin Alexa				
2.4. Year of study	II	2.5. Semester	2	2.6. Type of evaluation	E	2.7. Type of course unit	Content[1)]	**DS**
							Type[2)]	**DI**

[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	**40**	Lecture	**20**	Practicals/Tutorials	**20**

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	**38**
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	**40**
3.2.4. Preparation for exam	**4**
3.2.5. Other activities	**0**

3.3. Total hours of individual study	**110**
3.4. Total hours per semester	**150**
3.5. ECTS	**6**

4. Prerequisites (if necessary)

4.1. curriculum	Standard Model
4.2. competences	Standard Model and interaction of particles

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 high energy 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 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 provide a pedagogical introduction to the Monte Carlo (MC) simulation software tools, one of the computational pillars of any High Energy Physics (HEP) experiment, an extremely useful and efficient development tool in high-energy physics. This course is an elementary and practical introduction to the existing MC software tools in particle physics, providing an accessible, self-contained account of the basic concepts.
7.2. Specific objectives	Learning the technique to simulate high-energy physics interactions and detector responses by applying random samplings to probability distribution modelling experiments. Specific objectives will include the motivation, a brief history of its development, what are MC methods, why are they useful, Monte Carlo for event generation and Monte Carlo for detector response simulation.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations/ hours
Event simulation. Overview. Initialization & Program flow. Settings scheme. Particle Data Scheme. Setup run. Process selection. Particles and decays. Hadronization. Study the output.	Systematic exposition - lecture. Examples.	14 hours
Detector simulation. Simulation of the detector response. Object reconstruction. High-level corrections. Jet energy scale correction. Pile-up substraction. Validation with experimental data.	Systematic exposition - lecture. Examples.	6 hours

Bibliography:
1. Particle Data Group - The Review of Particle Physics (2024) https://pdg.lbl.gov/2024/
2. Kazunori Hanagaki, Junichi Tanaka, Makoto Tomoto, Yuji Yamazaki, Experimental Techniques in Modern High-Energy Physics - A Beginner‘s Guide, Lecture Notes in Physics, Springer, 2022 https://library.oapen.org/bitstream/handle/20.500.12657/61321/978-4-431-56931-2.pdf?sequence=1&isAllowed=y
3. PYTHIA 8, https://pythia.org/manuals/pythia8312/Welcome.html
4. MadGraph5_aMC@NLO, http://madgraph.phys.ucl.ac.be/
5. Delphes - a C++ framework, performing a fast multipurpose detector response simulation.

https://cp3.irmp.ucl.ac.be/projects/delphes 6. GEANT4 – A toolkit for the simulation of the passage of particles through matter, https://geant4.web.cern.ch/ 7. HEPForge, https://www.hepforge.org/ 8. ROOT - An open-source data analysis framework used by high energy physics, https://root.cern/		
8.2. Tutorials [main themes]	Teaching and learning techniques	Observations/hours
Problems specific for each section of the course.	Guided work.	10 hours
Event generators for high-energy particle collisions. Particles collisions. Hands-on examples. Running examples. Simple and macro-based analysis. Modifying configuration file. Adding new module. Elaboration of new examples.	Guided work.	10 hours
Bibliography: 1. Kazunori Hanagaki, Junichi Tanaka, Makoto Tomoto, Yuji Yamazaki, Experimental Techniques in Modern High-Energy Physics - A Beginner's Guide, Lecture Notes in Physics, Springer, 2022 https://library.oapen.org/bitstream/handle/20.500.12657/61321/978-4-431-56931-2.pdf?sequence=1&isAllowed=y 2. PYTHIA 8, https://pythia.org/manuals/pythia8312/Welcome.html 3. MadGraph5_aMC@NLO, http://madgraph.phys.ucl.ac.be/ 4. Delphes - a C++ framework, performing a fast multipurpose detector response simulation. https://cp3.irmp.ucl.ac.be/projects/delphes 5. GEANT4 – A toolkit for the simulation of the passage of particles through matter, https://geant4.web.cern.ch/ 6. HEPForge, https://www.hepforge.org/ 7. ROOT - An open-source data analysis framework used by high energy physics, https://root.cern/		

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	Written test/oral examination	40%
10.5.1. Tutorials	- ability to use specific problem solving methods - ability to analyse the results	Homeworks/Numerical reports	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
4.10.2024

Teacher's name and signature

Michele Renda
Călin Alexa,
[redacted]

Practicals/Tutorials instructor(s) name(s) and signature(s)

Michele Renda [redacted]
Călin Alexa,

Date of approval

Head of Department
Lect.dr. Roxana Zus
[redacted]