CYA Syllabus

Number & Title of Course: Particle Physics

Semester / Year and Location(s): Spring Semester / 2024 - N.C.S.R. "Demokritos"

Course Instructor(s): Evangelia Drakopoulou

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(Office) Hours Available: TBA

Course Description

Have you ever wondered what matter is made of? What is antimatter? Why is our Universe made from matter? Which forces govern the Universe? How do particle physics experiment work and how can humans accelerate particles?

This course will address these and many others questions. We will learn about the elementary particles of nature and the fundamental principles that govern their interactions. We will cover a variety of particle physics experiments and understand the instrumentation and physics goals of each one. During this course you will also learn how to read scientific papers and successfully present your physics experiment via talks and posters. You will learn how to program in Python and how to use modern analysis techniques for data exploration and analysis. At the end of this course you will have a solid background on particle physics theory and experiments.

Course Approach

The course topics will be explored by reading particle physics bibliography and scientific papers from particle physics experiments. Each class will be followed by short writing assignments to help understand each topic. Students will have first-hand experience in particle physics experiments during the lab visits. They will develop their presentation skills via presentations and posters and they will gain valuable knowledge in scientific programming and data analysis.

Learning Objectives

By the of the course you will be able to:
- understand the theory of particle physics
- solve exercises and problems in particle physics
- program in Python (one of the major programming languages used in particle physics and beyond) • analyze particle physics data
- efficiently present scientific work in talks and posters
- recognise the main instrumentation of particle physics experiments
- interpret a scientific paper

Course Requirements

At the end of each class some bibliography reading will be required along with short exercises for practice with delivery date the following week (see Assignment 1).
During Week IVb, Va, Vb these will be replaced by computing assignments (see Assignment 2). During Week XI students will give a 15-minute talk on a physics experiment and present a poster (see Assignment 3).

Classroom attendance is required for this course. Each absence (with no valid reason) will reduce the final grade by 3%.
The final exam (written) will consist of exercises to solve.

Class Field Work

During Week VI researchers of the Institute of Nuclear and Particle Physics (INPP) will provide seminars on: nuclear physics, particle and astroparticle physics and theory. Lab visits to the INPP research labs will follow. During these lab visits students will become familiar with the instrumentation and methodology required for particle physics experiments and further expand the theoretical knowledge acquired during previous classes.

CYA Field Study

Not Applicable

Evaluation and Grading

Your grade for this course will be based on the following distribution:

Percentages

Assignment 1 - Exercises: Homework assignments every week. All assignments will contribute 10% to the final grade.

Assignment 2 - Computing exercises I, II, III. These exercises will contribute 20% to the final

grade.

Assignment 3 - Talk and poster contributing 12% and 8% respectively to the final grade.

Final exam - 50% of the final grade.

Evaluation Criteria - Course Assignments

Assignment 1: Exercises

Description: Exercises will be solved during each class. Each week similar exercises will be given for home work with a delivery date the following week. These weekly assignments will amount to 10% (in total) of the final grade.

• Criteria 1: Correct solution and correct methodology

Assignment 2: Computing exercises

Description: After each programming session a series of computing exercises will be given for homework with delivery date the following week. These assignments will amount to 20% of the final grade.

• Criteria 1: Correct solution and correct methodology

Assignment 3: Talk and poster describing a Particle Physics experiment

Description: A 15-minute talk and a poster will be prepared to describe a particle physics experiment. This assignment will amount to 20% of the final grade.

• Criteria 1: Understanding the theory and the methodology of the experiment.
• Criteria 2: Slides and poster clarity and appearance
• Criteria 3: Presentation skills

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CYA Regulations and Accommodations

Attendance Policy

CYA regards attendance in class and on-site (in Athens or during field study trips) as essential. Absences are recorded and have consequences. Illness or other such compelling reasons which result in absences should be reported immediately to the Student Affairs Office.

Policy on Original Work

Unless otherwise specified, all submitted work must be your own original work. Any ideas taken from the work of others must be clearly identified as quotations, paraphrases, summaries, figures etc., and accurate internal citations and/or captions (for visuals) as well as an accompanying bibliography must be provided (Check the Student Handbook, pg. 7).

Use of Laptops

In-class or onsite use of laptops and other devices is permitted if this facilitates course-related activities such as note-taking, looking up references, etc. Laptop or other device privileges will be suspended if devices are not used for class-related work.

Class Schedule

To be updated every semester

Class Day	Day/Date/Place (if applicable)	Topic / Readings / Assignments Due
1	Week Ia	**Introduction to Particle Physics** *Description* An introduction to particle physics basic theory and concepts will be provided. The Standard Model of Physics with particles and antiparticles will be explained along with the concept of Feynman diagrams. *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 1-7 *Optional bibliography* Perkins 2000: 1-12 Halzen & Martin 1984: 1-14 Griffiths 2004: 189-211 *Required assignment* • Exercises (Assignment 1)
2	Week Ib	**Basic concepts of Particle Physics** *Description* Basic concept of Particle physics will be explained: Particle exchange, units and dimensions, Relativistic transformations. *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 18-24 Perkins 2000: 13-32 *Optional bibliography*

		Perkins 2000: 35-42 Halzen & Martin 1984: 14-27 *Required assignment* • Exercises (Assignment 1)
3	Week IIa	**Leptons** *Description* Lepton numbers and weak interactions. *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 27-38, 219-230 Griffiths 2004: 103-137, 301-338 *Optional bibliography* Perkins 2000: 46-51 *Required assignment* • Exercises (Assignment 1)
4	Week IIb	**Neutrinos** *Description* Neutrinos masses and Neutrinos mixing. Neutrino oscillations and modern neutrino experiments will be discussed. *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 38-49 *Optional bibliography* Perkins 2000: 284-298 Griffiths 2004: 65-72 *Required assignment* • Exercises (Assignment 1)
5	Week IIIa	**Quarks and Hadrons** *Description* Description of quarks, hadrons and allowed interactions. *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 51-73 *Optional bibliography* Perkins 2000: 95-139 Griffiths 2004: 257-258, 273-276, 279-288 *Required assignment* • Exercises (Assignment 1)
6	Week IIIb	**Experimental Methods I** *Description* The experimental methods will be discussed emphasizing the physical principles

		behind the methods. In the first session the accelerators and beams will be presented and the particle interactions with matter will be discussed. *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 75-92 *Required assignment* • Exercises (Assignment 1)
7	Week IVa	**Experimental Methods II** *Description* The experimental methods will be discussed emphasizing particle detectors, physics experiments and major discoveries. At the end of this session students will be given a list of experiments in particle physics. Each student will choose an experiment to study. In week XI students will present the chosen experiment in the class. *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 92-114 *Required assignment* • Exercises (Assignment 1)
8	Week IVb	**Basic Programming for Particle Physics** *Description* Efficient programming is a major aspect of Particle Physics for both theoretical and experimental research. Python is a common language used in particle physics and beyond. During this session an overview of python programming will be provided focusing on tools used in particle physics. *Required reading* Class slides with theory and hands-on exercises. During this session laptop is required. *Required assignment* • Exercises I (Assignment 2)
9	Week Va	**Data Analysis for Particle Physics I** *Description* During this session the major data analysis tools for particle physics will be discussed. *Required reading* Class slides with theory and hands-on exercises. During this session a laptop is required. *Required assignment* • Exercises II (Assignment 2)
10	Week Vb	**Data Analysis for Particle Physics II** *Description* During this session the major data analysis tools for particle physics will be discussed. Open data from a physics experiment will be analyzed.

		Required reading Class slides with theory and hands-on exercises. During this session laptop is required. *Required assignment* • Exercises III (Assignment 2)
11	Week VI (a,b)	**Seminars on Nuclear and Particle Physics** *Description* During these classes, seminars will be provided by researchers of the Institute of Nuclear and Particle Physics (INPP) on the following topics: nuclear physics, particle and astroparticle physics and theory. Building on previous classes these seminars will expand students' knowledge of these topics. Lab visits to the INPP research labs will follow. *Optional bibliography* Researchers will suggest scientific papers for each field.
12	Week VIIa	**Space-Time Symmetries** *Description* The transitional and rotational invariance, parity and charge conjugation will be discussed. *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 117-138 *Required assignment* • Exercises (Assignment 1)
13	Week VIIb	**DISCRETE SYMMETRIES: *C, P, CP AND CPT*** *Description* P violation, C violation and CP Conservation will be discussed *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 279-305 *Required assignment* • Exercises (Assignment 1)
14	Week VIIIa	**BEYOND THE STANDARD MODEL I** *Description* *Required reading* Class slides with theory and exercises Martin & Sahw 2008: 307-323 *Required assignment* • Exercises (Assignment 1)
15	Week VIIIb	**BEYOND THE STANDARD MODEL II** *Description* *Required reading* Class slides with theory and exercises

		Martin & Shaw 2008: 324-333 *Required assignment* • Exercises (Assignment 1)
16	Week IXa	**Relativistic Kinematics** *Description* *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 335-340 *Required assignment* • Exercises (Assignment 1)
17	Week IXb	**Amplitudes and Cross Sections** *Description* *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 343-348 *Required assignment* • Exercises (Assignment 1)
18	Week Xa	**Weak Interactions: Quarks and Leptons** *Description* *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 219-239 *Required assignment* • Exercises (Assignment 1)
19	Week Xb	**Weak Interactions: Electroweak Unification** *Description* *Required reading* Class slides with theory and exercises Martin & Shaw 2008: 249-276 *Required assignment* • Exercises (Assignment 1)
20	Week XI (a,b)	**Talk and poster describing a Particle Physics experiment** *Description* Students will present their chosen particle physics experiment in 15 min. Questions and discussion in class will follow. *Required reading* Scientific Papers of the chosen experiment *Required assignment* • Slides and poster (Assignment 3) *Optional bibliography* PhD/MSc thesis for the chosen experiment

21	Week XII (a,b)	**Revision exercises** *Description* This week will be devoted to particle physics exercises in order to better digest the material discussed and be prepared for the final exams. *Required reading* Class exercises
22	Week XIII	**Final exams** *Description* Written exams. *The final exams will amount to 50% of the final grade.*

Note from instructor: This is an indicative course schedule.
N.B.: The course schedule, in terms of subjects and readings, may be subject to change to benefit student learning and to keep up to date with current research.

COURSE BIBLIOGRAPHY

Griffiths, D. *Introduction to Elementary Particles.* Blackwell, 2004.
Halzen, F. and A. Martin. *Quarks & Leptons: An Introductory Course in Modern Particle Physics*. Wiley, 1984.
Martin, B.R. and G. Shaw. *Particle Physics.* 3rd edition. Wiley, 2008.
Perkins, D. *Introduction to High Energy Physics*. 4th edition. Cambridge University Press, 2000.