A COURSE SYLLABUS – DOCTORAL SCHOOLS
REGARDING THE QUALIFICATION CYCLE
FROM2020 TO 2024
AND FROM 2021 TO 2025

GENERAL INFORMTION ABOUT COURSE	
Course title	**Kinematics of elementary particles**
Name of the unit running the course	Doctoral School of University of Rzeszów
Type of course *(obligatory, optional)*	obligatory
Year and semester of studies	2-nd and 3-rd year; winter semester 2022/2023
Discipline	Physics
Language of Course	English
Name of Course coordinator	Prof. dr hab. Antoni Szczurek
Name of Course lecturer	Prof. dr hab. Antoni Szczurek
Prerequires	Passed course in fundamentals of nuclear physics and high physics , Passed course in quantum physics

BRIEF DESCRIPTION OF COURSE

The main objective of the course is to learn the principles of kinematics of elementary particles and the possibility of describing the results of experiments with the help of theoretical models of the collisions carried out. Auditing exercises are aimed at practical familiarization with the problems of particle kinematics, in particular elastic proton-proton collisions with pomeron exchange through active participation in the discussion on obtaining the results of theoretical predictions of the mentioned processes. The learning outcome is the acquisition of skills and competencies regarding the creation and use of phenomenological models to predict the results of particle collisions.

The purpose of this short course is to present simple kinematic issues of high-energy physics using several contemporary examples. It is proposed to consider the considered well-studied issue of proton-proton elastic scattering in the high-energy region in connection with current experimental measurements. In particular, the problem of the difference of proton-proton and proton-antiproton interactions will be considered. Attempts to explain these differences will also be presented. Since these processes were measured for different energies it is necessary to understand not only the kinematics but also the dependence of the dynamics on kinematic variables. Some of the issues will be presented diagrammatically.

In recent years there have been a number of discoveries of new particles, often very exotic. Examples $(\left(X(3872), X(6900)\right)$ will be discussed. Some of these particles are considered $q\bar{q}$-type states, some are so-called tetraquarks, and some are hadron-type molecules. The resolution of this issue is complicated, so various analyses will be presented to explain the frequency of production of these particles, proposing specific production mechanisms.

COURSE LEARNING OUTCOMES AND METHODS OF EVALUATING LEARNING OUTCOMES				
Learning outcome	The description of the learning outcome defined for the course	Relation to the degree programme outcomes (symbol)	Learning Format (Lectures, classes,...)	Method of assessment of learning outcomes (e.g. test, oral exam, written exam, project,...)
Knowledge (no.)				
1.	The doctoral student knows and understands the global body of work covering the theoretical foundations of elastic and semielastic collision kinematics,	P8S-WG/1	l,ex	discussion, oral exam
2.	Knows and understands the principles of kinematics of deep-inelastic collisions of elementary particles;	P8S-WG/1	l,ex	discussion, oral exam
3.	Knows and understands the pomeron model and its role in the theoretical explanation of experimental results;	P8S-WG/2	l,c	discussion
4.	Knows and understands the latest discoveries in the field of elementary particles;	P8S-WG/3	l,c	discussion
Skills (no.)				
1	A doctoral student is able to use knowledge of particle kinematics to make theoretical predictions of experiments conducted on particle accelerators, is able to define the goal and object of research, formulate a research hypothesis, apply the learned research techniques and tools to achieve the the established goal,	P8S-UW/1	l,c	discussion
2	Is able to critically analyze and evaluate the results of scientific research in the discipline of physical sciences;	P8S-UW/2	l,c	discussion
3	Is able to initiate debate and participate in scientific discourse on selected computational methods of particle physics;	P8S-UK/3, P8S- UK/4; P8S-UK/1; P8S-UK/5	l,c	discussion
Social skills (no.)				

1	The doctoral student is ready to recognize the importance of accumulated knowledge in solving practical problems of elementary particle kinematics;	P8S-KK/3	l		discussion
2	The doctoral student is ready to critically evaluate achievements within the discipline of physical sciences;	P8S-KK/1	l		discussion
3	The doctoral student is ready to act in the public interest;	P8S-KO/2	l		discussion

LEARNING FORMAT – NUMBER OF HOURS

Semester (no.)	Lectures	Classes	Lab	Internships.	Others	**ECTS**
III i V	5	10				0

METHODS OF INSTRUCTION

lecture - lecture with multimedia presentation using a computer and overhead projector, discussion
laboratory exercises: discussion, problem solving

COURSE CONTENT

Lecture/Conversation:

1. Four-vectors and kinematic variables
2. Deep-inelastic collisions.
3. Elastic proton-proton collisions.
4. Mechanisms of production of exotic particles.
5. Decays of exotic particles.

COURSE ASSESSMENT CRITERIA

Attendance at classes and active participation in the discussions held during them, oral credit carried out during the last class checking the degree of the program content acquired during the class.
The condition for passing is a minimum of 50% correct answers.
Percentage range of correct answers for the grade:
51-60% - 3.0
61-70% - 3.5
71-80% - 4.0
81-90% - 4.5
91-100%- 5.0

TOTAL PhD STUDENT WORKLOAD REQUIRED TO ACHIEVE THE INTENDED LEARNING OUTCOMES – NUMBER OF HOURS AND ECTS

Activity	Number of hours
Scheduled course contact hours	15
Other contact hours involving the teacher (consultation hours, examinations)	1
Non-contact hours – student`s own work (preparation for classes or examinations, project, etc.)	20
TOTAL NUMBER OF HOURS	36

TOTAL NUMBER OF ECTS	
INSTRUCTIONAL MATERIALS	
Compulsory literature:	1. *Elementary Particle Physics – Concepts and Phenomena,* Otto Nachmann, 1990 2. *A modern introduction to particle physics,* Fayyazuddin Riazuddin, 2022
Complementary literature:	1. *Review of Particle Physics*, Particle Data Group, European Physical Joournal C15, 2000 2. M.Poppe, *Exclusive hadron production in two-photon reactions*, International Journal of Modern Physics A, Vol.1, No.3 (1986) 545-668