

**COURSE SYLLABUS – DOCTORAL SCHOOL  
EDUCATION CYCLE FROM 2024/2025 TO 2027/2028**

<b>GENERAL INFORMATION ABOUT THE COURSE</b>				
Course title	<b>DOCTORAL SEMINAR</b>			
Name of the unit delivering the course	Doctoral School at the University of Rzeszów			
Type of course (compulsory, elective)	<b>compulsory course</b>			
Year/semester	Year I–IV, semester: I–VII			
Discipline	Physical Sciences			
Language of instruction	English			
Course coordinator (name and surname)	<b>dr hab. Marta Łuszczak, prof. UR</b>			
Name and surname of the instructor(s)	<b>dr hab. Marta Łuszczak, prof. UR</b>			
Prerequisites	In-depth knowledge of: general physics, theoretical mechanics, quantum mechanics, elementary particle physics, as well as English language proficiency at the B2 level.			
<b>COURSE SUMMARY</b> (a concise description of the content and objectives of the course; 100–200 words)				
<p>The doctoral seminar is intended for systematic presentation and critical discussion of the progress of research conducted as part of the preparation of a doctoral dissertation in the discipline of physical sciences. The classes include a literature review, refinement of the dissertation research problem, formulation of hypotheses and objectives, development of the theoretical formalism, and implementation and verification of numerical calculations. In the substantive part, photon-initiated exclusive and diffractive processes (photon–photon fusion, <math>\gamma\gamma</math>; photon–proton interactions, <math>\gamma p</math>; and virtual photon–proton, <math>\gamma^* p</math>) in hadronic and lepton–hadron collisions are discussed, including issues of the proton structure described by generalized parton distributions (GPD, Generalized Parton Distributions) and generalized transverse-momentum dependent distributions (GTMD, Generalized Transverse-Momentum Dependent Distributions). The seminar supports the preparation of conference presentations, scientific papers and subsequent parts of the dissertation, and develops competences in communication in English and work in an international environment.</p>				
<b>LEARNING OUTCOMES FOR THE COURSE AND VERIFICATION METHODS *</b>				
Learning outcome symbol	Intended learning outcomes	Reference to learning outcomes for qualifications at PRK level 8 (symbol)	Form of classes (lect., classes, etc.)	Verification methods (e.g.: test, oral exam, written exam, project, etc.)
<b>Knowledge: No.</b>	<b><i>knows and understands, has knowledge</i></b>			
<b>P8S_WG1</b>	knows and understands advanced issues of high-energy physics and the current scientific output (including global) in the area of photon-initiated exclusive and diffractive processes and the structure of hadrons, in particular in the description using generalized parton distributions (GPD, Generalized Parton Distributions) and generalized transverse-momentum dependent	P8S_WG	seminar	oral presentation, discussion

	distributions (GTMD, Generalized Transverse-Momentum Dependent Distributions);			
<b>P8S_WG2</b>	knows the directions of the development of scientific research and the latest discoveries in elementary particle physics, including research conducted at accelerators (LHC, Large Hadron Collider; EIC, Electron-Ion Collider; JLab, Thomas Jefferson National Accelerator Facility), relating them to the issues of photon processes, deep inelastic scattering (DIS, Deep Inelastic Scattering) and diffractive jet production.	P8S_WG	seminar	oral presentation, discussion
<b>P8S_WG3</b>	knows, understands and is able to use the terminology and specialist concepts used in high-energy physics and related disciplines, at the level appropriate for the discipline of physical sciences.	P8S_WG	seminar	oral presentation
<b>Skills: No.</b>	<i>is able to</i>			
<b>P8S_UW1</b>	based on the possessed knowledge, is able to identify and solve research problems, define the objective and research hypothesis, select and improve techniques, methods and computational tools (analytical and numerical), and draw inferences on the basis of the obtained results concerning exclusive and diffractive processes.	P8S_UW	seminar	oral presentation, discussion
<b>P8S_UW2</b>	is able to conduct a critical review of the scientific literature, select and use sources to diagnose research problems, design analyses, and create elements of scientific output (e.g., calculations, simulations, implementations in code) while observing good practices of documentation and citation.	P8S_UW	seminar	oral presentation, discussion
<b>P8S_UW3</b>	is able to analyse and critically evaluate research results (own and others'), including assessing uncertainties and limitations of models, interpreting results in the context of the literature and data, and formulating conclusions and	P8S_UW	seminar	oral presentation, discussion

	recommendations concerning subsequent stages of research.			
P8S_UK6	is able to publicly present research results and participate in discussion on scientific and professional topics in an international environment, using English at least at B2 level of the Common European Framework of Reference for Languages.	P8S_UK	seminar	oral presentation, discussion
<b>Social competences: No.</b>	<i>is ready to</i>			
P8S_KK1	is ready to critically evaluate achievements within the discipline of physical sciences and to critically evaluate the contribution of the results of own research activity to the development of this discipline, with respect for the principles of research ethics, scientific integrity and protection of intellectual property.	P8S_KK	seminar	oral presentation, discussion
P8S_KK3	is ready to solve cognitive and practical problems arising in research work, including cooperation in a team, responsible communication of results (presentations, preprints, publications) and planning further scientific development.	P8S_KK	seminar	oral presentation, discussion

#### FORMS OF CLASSES, NUMBER OF HOURS AND POINTS

Semester (no.)	Lect.	Classes/Tutorials	Lab.	Internship	Other	Number of ECTS credits
I - VII	-	-	-	-	7 x 15 hrs - 105 hrs	14

#### TEACHING METHODS

scientific discussion; study of scientific literature; preparation and presentation (in English) of the research objective, research methods, calculation results and conclusions; analysis and reviewing of articles; written assignments (paper, semester report, outline of an article/chapter); consultations; monitoring progress in the preparation of scientific publications and the doctoral dissertation.

#### COURSE CONTENT

**Curriculum content covered throughout the entire course of study in the subject Doctoral Seminar: semester I**

Topic: Review of the literature on photon-induced and exclusive processes; refinement of the dissertation research problem.

Topic: Introduction to generalized parton distributions (GPD) and generalized transverse-momentum dependent distributions (GTMD); discussion of kinematics and observables.

Topic: Preparation of the research plan (Individual Research Plan) and presentation of the assumptions of the doctoral dissertation.

**semester II**

Topic: Development of the theoretical formalism for the selected process (e.g., diffractive dijet production in deep inelastic scattering, DIS) and discussion of GPD models.

Topic: Preparation of the computational toolkit (numerical tools, tests, validation) and initial calculations of observables.

Topic: Presentation and critical analysis of preliminary results; discussion of hypotheses, objectives and schedule.

**semester III**

Topic: Analysis of processes initiated by single and double photon exchange ( $\gamma p$ ,  $\gamma\gamma$ ) in proton–proton and proton–nucleus ( $pp$ ,  $pA$ ) collisions at LHC energies.

Topic: Assessment of the impact of kinematic and model parameters; estimation of uncertainties and comparison with the literature and available data.

Topic: Preparation of a conference contribution (abstract, slides) and a seminar summarizing the research stage.

**semester IV**

Topic: Extension of the research to lepton–hadron ( $ep$ ,  $eA$ ) processes in the EIC context; selection of observables sensitive to GPD/GTMD.

Topic: Implementation and numerical tests (including elements of a Monte Carlo generator) and interpretation of results.

Topic: Preparation of the first manuscript of a scientific article (structure, introduction, formalism, results) and its discussion.

**semester V**

Topic: Exclusive meson production (heavy and/or light) and diffractive processes – analysis of amplitudes and cross sections; verification against results of other groups.

Topic: Preparation of results for publication (plots, tables, description of uncertainties) and preparation of responses to internal/reviewer comments.

Topic: Presentation of results in English and conducting a scientific discussion.

**semester VI**

Topic: Finalization of calculations, systematic analysis and code consolidation; preparation of the second article or an extension of results.

Topic: Planning the structure of the doctoral dissertation and preparing chapters (methods, results, discussion) based on the completed research.

Topic: Preparation of conference materials and a seminar summarizing annual progress.

**semester VII**

Topic: Synthesis and comparison of results from several processes; formulation of conclusions and research perspectives.

Topic: Editing and finalization of the doctoral dissertation; supplementing the literature review and ensuring coherence of method descriptions.

Topic: Preparation of the defence presentation and summary of achievements (publications, conferences, collaboration).

**COURSE COMPLETION REQUIREMENTS (ASSESSMENT CRITERIA)**

Course completion is based on continuous assessment of the doctoral student's work in each semester. In particular, the following are assessed: systematic preparation and delivery of seminar presentations, active participation in discussion, completion of research tasks in accordance with the plan, preparation of written materials (semester reports, papers, outlines of articles/chapters) and

documented progress in preparing scientific publications and the doctoral dissertation. Possible semester grades: 2.0, 3.0, 3.5, 4.0, 4.5, 5.0.

**TOTAL STUDENT WORKLOAD REQUIRED TO ACHIEVE THE INTENDED LEARNING OUTCOMES  
IN HOURS AND ECTS CREDITS**

Form of activity	Average number of hours to complete the activity
Hours completed in direct contact resulting from the study programme	<b>7 x 15 hrs – 105 hrs</b>
Other with the teacher's participation (participation in consultations, exam)	<b>6</b>
Hours completed independently by the doctoral student (preparation for classes, exam, writing a paper, etc.)	<b>309</b>
<b>TOTAL HOURS</b>	<b>420</b>
<b>TOTAL NUMBER OF ECTS CREDITS*</b>	<b>14</b>

**LITERATURE**

Basic literature:	<ol style="list-style-type: none"> <li>1) M.E. Peskin, D.V. Schroeder, An Introduction to Quantum Field Theory, Addison-Wesley (1995).</li> <li>2) F. Halzen, A.D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics, Wiley (1984).</li> <li>3) D.H. Perkins, Introduction to High Energy Physics, Cambridge University Press (subsequent editions).</li> <li>4) R.K. Ellis, W.J. Stirling, B.R. Webber, QCD and Collider Physics, Cambridge University Press (1996).</li> <li>5) J.C. Collins, Foundations of Perturbative QCD, Cambridge University Press (2011).</li> <li>6) R. Devenish, A. Cooper-Sarkar, Deep Inelastic Scattering, Oxford University Press (2004).</li> <li>7) A. Donnachie, H.G. Dosch, P.V. Landshoff, O. Nachtmann, Pomeron Physics and QCD, Cambridge University Press (2002).</li> <li>8) M. Diehl, Generalized parton distributions, Phys. Rept. 388 (2003) 41.</li> <li>9) A.V. Belitsky, A.V. Radyushkin, Unraveling hadron structure with generalized parton distributions, Phys. Rept. 418 (2005) 1.</li> </ol>
Supplementary literature:	<ol style="list-style-type: none"> <li>1) J.R. Forshaw, D.A. Ross, Quantum Chromodynamics and the Pomeron, Cambridge University Press (1997).</li> <li>2) V.M. Budnev et al., The two-photon particle production mechanism, Phys. Rept. 15 (1975) 181.</li> <li>3) M. Guidal, M.V. Polyakov, A.V. Radyushkin, M. Vanderhaeghen - selected review papers on GPD and DVCS.</li> <li>4) The Electron-Ion Collider (EIC) Yellow Report - review materials and technical documents.</li> <li>5) Documentation of selected Monte Carlo generators for photon-induced processes (e.g. STARlight, SuperChic) and related publications.</li> <li>6) R.K. Bock et al., Data Analysis Techniques for High-Energy Physics, Cambridge University Press (subsequent editions).</li> <li>7) G. Dissertori, I. Knowles, M. Schmelling, Quantum Chromodynamics: High Energy Experiments and Theory, Oxford University Press (2003).</li> </ol>

*\* (1 ECTS CREDIT CORRESPONDS TO 25–30 HOURS OF THE TOTAL STUDENT WORKLOAD REQUIRED TO ACHIEVE THE INTENDED LEARNING OUTCOMES)*

.....

Date and signature of the course instructor

.....

Approval of the Head of the Unit or an authorised person