Subject content

1. Information about the study programme

1.1 University	West University of Timişoara
1.2 Faculty	Physics and Mathematics
1.3 Department	Physics
1.4 Study direction	Physics
1.5 Study cycle	Master
1.6 Study programm	**Advanced research methods in physics** / conform COR: fizician (211101); profesor în învăţământul gimnazial (232201 - în condiţiile legii); asistent de cercetare (248102); referent de specialitate în învăţământ (235204); analist (213101); analist financiar (241493).

2. Information about the subject/discipline

2.1 Name	Effective Models in Quantum Chromodynamics						
2.2 Course coordinator	Sergio MORALES-TEJERA						
2.3 Seminar coordinator	Matteo BUZZEGOLI						
2.4 Year of study	II	**2.5 Semester**	I	**2.6 Type of assessment**	E	**2.7 Type of discipline**	DS/DFAC/ARMP 2406

3. Total estimated time (hours of teaching per semester)

3.1 Number of hours per week	**4**	**3.2 course**	**2**	**3.3 seminars/labs**	**2**
3.4 Total hours in the curriculum	**56**	**3.5 course**	**28**	**3.6 seminars/labs**	**28**

Distribution of time:	**hours**
Study based on Instructions, course materials, bibliography and notes	**33**
Additional documentation library, specialized electronic platforms / field	**14**
Training seminars / laboratories, homework, essays, portfolios and essays	**28**
Tutoring	**7**
Examinations	**12**
Other activities	

3.7 Total hours of individual study	**94**
3.8 Total hours per semester	**150**
3.9 Number of credits	**6**

Adresă poştală: Bd. Vasile Pârvan nr. 4, cod poştal 300223, Timişoara, jud. Timiş, România
Număr de telefon: +40-(0)256-592.300 (310)
Adresă de e-mail: HYPERLINK "mailto:secretariat@e-uvt.ro"secretariat@e-uvt.ro
Website: HYPERLINK "http://www.uvt.ro/"www.uvt.ro

4. **Prerequisites (where applicable)**

4.1 of curriculum	• Quantum fields (ARMP1206) • Symmetries in physics (ARMP 1105) • Standard model (ARMP 1207)
4.2 of skills	• General skills: ability to assimilate fundamental knowledge; correct usage of physics-specific terminology; ability to work individually and as part of a team; • Professional skills: the correct identification and usage of the main laws and principles of physics; ability to solve physics-specific problems.

5. **Conditions (where applicable)**

5.1 for the course	-
5.2 for the seminar	-

6. **Discipline objectives – learning outcomes**

Knowledge	• Accurately applying the fundamental laws and principles of physics that pertain to this course within a specific context. • Understanding the phase diagram of QCD and its phase transitions. • Epistemological control over the most commonly used effective models of QCD.
Skills	• Solving physics problems through both analytical and numerical methods. • Interpretation of results from effective models in terms of quark-gluon plasma phenomenology. • Ability to generalise the effective models to include additional effects.
Responsibility and autonomy	• Acquaintance with modern techniques in quantum field theory. • Understanding the state-of-the-art for the given topic. • Acquiring knowledge regarding the strong interaction.

7. **Contents**

7.1. Course	**Teaching methods**	**Observations**
Chap.1. Introduction to QCD (6 hours) ● High energy QCD: Asymptotic freedom. ● Global symmetries of QCD. ● Deconfinement and Chiral Symmetry Breaking phase transitions.	Interactive lecturing at the blackboard or using the beamer.	[1] Chap. 1, 2; [2] Chap. 1.3, 13, 14; [3] Chap. 2; [4] Sec. 2
Chap.2. QCD at finite temperature (6 hours) ● MIT bag model ● First principle approaches in QCD. ● Effective models of QCD.		[1] Chap. 2, 4, 5; [2] Chap. 10, 12, 15, 16; [4] Sec. 3, 4 [5] Chap. 7;
Chap. 3. Chiral Phase Transition (6 hours) ● Fermion condensate as the order parameter. ● Phase diagram in Nambu—Jona-Lasinio model. ● Phase diagram in Quak-Meson model.		[1] Chap. 6; [3] Chap. 3; [6] Sec. 1, 2, 3, 5, 7, 8

Chap. 4. Deconfinement Phase Transition (6 hours) • Polyakov loop as the order parameter. • Polyakov loop extended Nambu—Jona-Lasinio model. • Polyakov loop enhanced Quark-Meson model.		[6] Chap. 3, 10. [7] Sec. 4.5
Chap. 5. Applications to QGP physics. (4 hours) • Beam energy scan. • Criticality as a probe for phase transitions.		[1] Chap. 14; [2] Chap. 6, 7, 8

Bibliography

1. H. Yagi, T. Matsuda, Y. Miake, Quark-Gluon Plasma (Cambridge University Press, 2005).
2. J. Letessier, J. Rafelski, Hadrons and Quark-Gluon Plasma (Cambridge University Press, 2002)
3. A. Dobado, A. Gómez-Nicola, A. L. Maroto, J. R. Peláez, Effective Lagrangians for the Standard Model (Springer, 1997)
4. D. H. Rischke, The Quark-Gluon Plasma in Equilibrium (Prog. Part. Nucl. Phys. 52, 2004).
5. J. Rafelski, Melting Hadrons, Boiling Quarks (Springer Open, 2016)
6. S. P. Klevansky, The Nambu-Jona-Lasinio model of Quantum Chromodynamics (Rev. Mod. Phys. 64, 1992)
7. U. Reinosa, Perturbative Aspects of the Deconfinement Transition (Springer, 2022)

7.2. Seminar/laboratory	Teaching methods	Observations
Chap.1. Introduction to QCD (6 hours) • Yang-Mills fields. • β-functions in Quantum Field Theory. • Explicit breaking of chiral symmetry.		The bibliographic references follow those of the course.
Chap.2. QCD at finite temperature (6 hours) • MIT Bag Model. • Euclidean dimensional reduction. • Quasi-particle spectrum in a hot/dense medium.		
Chap. 3. Chiral Phase Transition (6 hours) • Matching Nambu-Jona-Lasinio to QCD. • Bosonization. • Landau function and order of the phase transition. • Fermi-Dirac integrals and dynamical mass generation.		
Chap. 4. Deconfinement Phase Transition (6 hours) • Imaginary chemical potential. • Polyakov loop potential. • Polyakov-enhanced Fermi-Dirac integrals. • Dynamical confinement/deconfinement phase transition.		
Chap. 5. Applications to QGP physics. (4 hours) • Trajectory of fireball in T-μ plane. • Effect of rotation.		

Bibliography
See 7.1. Course.

8. **Corroboration of the course contents with the epistemic expectations of the community representative, professional associations and representative employers of the programme itself**

Knowing and understanding the specific phenomena studied in this course, formation and development of practical abilities to correctly and completely interpret results, practice of the teamwork spirit and of the ability to organise and investigate, nurturing a scientific environment based on values, professional ethics and quality.

9. **Evaluation**

Type of activity	9.1 Evaluation criteria	9.2 Evaluation methods	9.3 Percentage of the final mark
9.4 Course	For 50% marks: fundamental notions from this field. For 100% marks: advanced notions from this field.	1. Written evaluation: theory questions. 2. Oral examination: a) elementary topics; b) advanced topics.	**25%** **25%**
9.5 Seminar	For 50% marks: fundamental notions from this domain. For 100% marks: advanced notions from this domain.	3. Written evaluation: Problem solving using computer simulations.	**50%**
9.6 Minimum performance standards			
• 50% marks for theory test; • 50% marks for problem test; • Oral examination on elementary topics. Alternatively: • 50% marks for theory test; • Written project on one of the course themes.			

- Minimum attendance: according to the applicable WUT regulations (course 50%; seminar 70%).
- Bonus points awarded for good attendance and for timely homework submission.

Date: 16.09.2025

Signature of Course leader:
Dr. Sergio Morales Tejera

[redacted]

Date of departamental validation:

Signature of Head of Department:

Conf. Dr. Nicoleta ȘTEFU