UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

DIPARTIMENTO INTERUNIVERSITARIO DI FISICA

General information	
Academic subject	Fundamental Interactions Phenomenology
Degree course	Master Course (Laurea magistrale) in Physics
Academic Year	2022-23
European Credit Transfer and Accumulation System (ECTS)	6
Language	English
Academic calendar (starting and ending date)	March 2023 - June 2023 (second semester)
Attendance	mandatory

Professor/ Lecturer	
Name and Surname	Pietro Colangelo
E-mail	pietro.colangelo@ba.infn.it
Telephone	+39-0805443210
Department and address	*INFN – Sezione di Bari/ Dipartimento di Fisica- Bari - via Orabona 4, 70126 Bari*
Virtual headquarters (Microsoft Teams code)	dtlh4tx
Tutoring (time and day)	Mon-Wed-Fri, 4 pm - 5 pm

Syllabus	
Learning Objectives	Deep and extended knowledge of the phenomenological aspects of the physics of the interactions among the elementary constituents of the matter (gravity excluded), of the interpretation schemes, of the basic principles, of the accuracy of the description, of present limitations, unsolved problems, and perspectives for new developments. The capability of making computations and quantitative comparisons between theory and experiment will be developed, together with the understanding the main issues involved in the high energy physics analyses.
Course prerequisites	Non-Relativistic Quantum Mechanics, basic Special Relativity, basic Quantum Field Theory
Contents	**Generalities** ○ Classical and quantum scattering of electrons by a heavy nucleus. Scattering matrix and scattering cross section. Unitarity relations and consequences. ○ Overview of total pp and ppbar cross sections. Decay rate of an unstable particle. **Strong Interaction Physics** ○ Multiparticle production at high energy, multiplicity, (pseudo)-rapidity. ○ Naive parton model: Deep inelastic scattering of electrons and neutrinos. Evidence of neutral flavourless partons. Drell-Yan process. Factorization formulae. ○ SU(2) and SU(3) groups in a nutshell. ○ Gauge principle. Lagrangian density of Quantum ChromoDynamics. Vacuum charge screening vs antiscreening, strong coupling constant and its running. ○ Asymptotic freedom vs confinement in QCD. ○ Advanced topics in strong interaction Physics: Hagedorn temperature, Cabibbo-Parisi diagram, QCD in extreme conditions of temperature and baryon density. QCD phase diagram. **EW Interaction Physics** ○ Gauge group of the Electroweak interactions. Description of the first lepton family and of its interactions. ○ Spontaneous breaking of a physical system symmetry. SSB of a continuous global symmetry and Goldstone bosons. Higgs field and the EW symmetry breaking.

	○ Description of the three lepton and quark families. Fermi theory recovered at low energy. Yukawa interaction terms. Fermion masses and mixings. ○ Lagrangian density of the Standard EW model. Higgs boson properties. ○ Computation of simple processes (h ->f bar f, Z0-> f bar f) and comparison with data. ○ SM description of CP violation. Measurement of the CKM matrix elements. The lepton sector. ○ Advanced topics: Problems the SM is not able to face. Examples of scenarios beyond SM.
Books and bibliography	O. Nachtmann. Elementary particle Physics. Concepts and Phenomena. Springer 1990 (main) G. Kane. Modern elementary particle physics. Cambridge University Press 2017 P. Langacker. The Standard Model and beyond. CRC Press 2017 For the exercises: N. Cartiglia. Manuale di esercizi di fisica delle particelle, Levrotto & Bella 2015
Additional materials	Written notes on selected issues about the advanced topics

Work schedule			
Total	Lectures	Exercises	Out-of-class study hours/ Self-study hours
Hours			
150	40	15	95
ECTS			
6	5	1	

Teaching strategy	
Teaching methods	○ Classroom lectures at the blackboard. ○ Guided exercises. ○ Dedicated lectures to a few topical arguments related to recent developments in physics of fundamental interactions.

Expected learning outcomes	
Knowledge and understanding on:	Deep understanding of the main aspects of the fundamental interactions, of their mutual correlations, of their ordering principles, of their experimental aspects and confirmations, of the unsolved issues and of the limitations of the present descriptions. The exercises made during the course are important to achieve such an understanding.
Applying knowledge and understanding on:	Acquisition of competences useful for research work. Development of learning, understanding, and reasoning methods useful for working activities far from research.
Soft skills	• **Making informed judgments and choices** Development of the individual critical skills, ingenuity, and capability of autonomously reaching conclusions and getting opinions about the various aspects of the fundamental interactions, and more in general. • **Communicating knowledge and understanding** Capability of communicating scientific concepts in direct, complete, and precise way, avoiding any jargon and logical shortcomings. • **Capacities to continue learning** Capability of approaching problems in an open minded, critical and innovative way.

Assessment and feedback	
Methods of assessment	Oral examination

Evaluation criteria	• **Knowledge and understanding** The student is required to ○ know the mains aspects of the strong and electroweak interactions. ○ know the physical principles and the phenomenological consequences. • **Applying knowledge and understanding** The student is required to know how to make numerical exercises about simple physical processes. • **Autonomy of judgment** The student is required to know and judge the limits and the open issues in the present description of fundamental interactions. • **Communicating knowledge and understanding** The student is required to know how to present scientific concepts and results in precise, careful, and direct way. • **Communication skills** ○ The clarity and the precision of the language are considered. • **Capacities to continue learning** ○ The capacity to autonomously collect relevant new information from books, articles and other sources is considered.
Criteria for assessment and attribution of the final mark	The oral examination aims at assessing the preparation of the candidate based on the above listed criteria. The final mark is attributed consequently.
Additional information	