UNIVERSITÀ DI PISA

FUNDAMENTAL INTERACTIONS / INTERAZIONI FONDAMENTALI

FRANCESCO FORTI

Anno accademico	2021/22
CdS	FISICA
Codice	305BB
CFU	9

Moduli	Settore/i	Tipo	Ore	Docente/i
INTERAZIONI FONDAMENTALI	FIS/04	LEZIONI	54	FRANCESCO FORTI GIOVANNI SIGNORELLI

Obiettivi di apprendimento

Conoscenze
Conoscenza quantitativa di base della fisica delle particelle elementari e delle loro interazioni, dal punto di vista fenomenologico e sperimentale. Conoscenza dello sviluppo temporale delle principale scoperte.

Modalità di verifica delle conoscenze
La verifica delle conoscenze acquisite avviene attraverso un colloquio di esame.

Capacità
Valutazione quantitativa di processi di scattering e decadimento di particelle elementari. Progettazione concettuale di esperimenti di fisica delle particelle

Modalità di verifica delle capacità
La verifica delle capacità acquisite avviene attraverso le discussioni degli esercizi proposti per casa e durante le esercitazioni e tramite un esame scritto che consiste nella risoluzione di alcuni esercizi.

Prerequisiti (conoscenze iniziali)
Conoscenze di elettromagnetismo avanzato, meccanica quantistica non relativistica e relatività ristretta. Competenze di calcolo differenziale, algebra lineare, calcolo con matrici, analisi nel piano complesso.
La frequenza al corso presuppone il completamento della laurea triennale, e in particolare il superamento degli esami di Fisica 3 e Meccanica Quantistica.

Indicazioni metodologiche
Il corso è organizzato con lezioni ed esercitazioni in aula con frequenza fortemente consigliata.

Programma (contenuti dell'insegnamento)
Module 1: Historical and phenomenological introduction (6)

- Experimental methods in particle physics. Sources: cosmic rays, reactors and isotopes, accelerators. Extracted beams and colliders
- Reminder of radiation detection techniques and detectors.
- Brief history of the discovery of elementary particles and construction of the Standard Model.[Experiments: Conversi, Pancini, Piccioni; Powell; Cowen Reines, Andersen]
- Photon, mesons, antiparticles, baryons, leptons, strange particles, quarks and gluons, intermediate vector bosons, Higgs bosons.
- Main characteristics of the fundamental interactions and Standard Model phenomenology.
- Forbidden and allowed diagrams in the SM.

Module 2: Basic methodology (10)

- Reminder of relativistic kinematics. Notation for 4-vectors. Mandelstam relativistic invariants. Natural units

- Scattering and decay. Mean life, width, cross section. Lorentz-invariant phase space. Transition matrix. Fermi golden rule.
- Relativistic equations: Klein-Gordon and Dirac. Classification of elementary particles: spin, fermions and bosons. Particles and anti-particles.
- Concept of Feynman diagrams and calculation methods

Module 3: Symmetries and conservation laws. (6)

- Symmetries, invariance, conservation laws, symmetry breaking.
- Discrete symmetries, C, P e T. Statement of CPT theorem.
- Intrinsic parity of particles (P). Parity of the pion. [Chinowsky and Steinberger experiment(1954) on slow pion capture on deuteron]
- Intrinsic charge conjugation (C). C for photon and ?0.
- Continuous symmetries and conservation laws. Statement of Noether theorem.
- Use of group theory and their representation. Angular momentum and composition rules.
- Isospin symmetry. Doublets (nucleon) and triplets (pion). Flavor SU(2) symmetry. G-Parity
- Baryons and mesons from ud quarks: n,p,?,?,?,?

Module 4: Electrodynamics (8)

- Feynman rules: identical particles in final state; sum on final states; average on initial states. Interaction as exchange of mediator particle.
- Charge conservation and gauge symmetry.
- QED Feynman diagrams.
- e+e- annihilation in a muon pair.
- Reminder of hydrogen levels, fine and hyperfine structure, Lamb shift.
- Positronium, level structure, decay channels.Parapositronium and ortopositronium

Module 5: Hadrons and strong interactions (12)

- Hadronic resonances. The 3/2+ ?
- Associated production of K – ?and strangeness discovery. S=-1, -2, -3 baryons
- Dalitz plotin three-body phase space. Angular momentum and parity of final states of two or three neutral or charged pions.
- Pseudo-scalar mesons. Strange mesons K. The theta-tau puzzle. ?, ?'.
- Vector bosons: ?,?, ?. ? decay in two charged and neutral pions.
- Approximate flavor SU(3) symmetry.Group derivation of quark model. Baryonic number. Organization in octets and decuplets.
- Pointlike nature of quarks in Deep Inelastic Scattering
- Hadronic production at e+e- colliders. Ratio R of hadronic production to muon pairs. Experimental evidence of quark colour.
- Discovery of the J/psi (charm) and of its excited states. [Richter and Ting experiments and the november revolution]
- Angular distribution of jets and quark spin. Events with tre hadronic jets and evidence of gluon.
- The third family and the completion of the quark model [Lederman experiment]
- Measurement of ?s. OZI selection rule.
- Concept of running coupling constants for ?QEDand ?s
- Feynman diagrams for hadronic processes.

Module 6: Weak interactions (12)

- Charged and neutral current interactions. Muon decay. Fermi constant and 4-fermion process.
- Neutron beta decay. Pion decay and helicity suppression.
- Neutrinos and conservation of leptonic flavor. Dirac and Majorana neutrino. Neutrinoless double beta decay [Experiment on muon neutrino flavor]
- Limits on neutrino masses. [Measurement with tritium]
- Parity violation in weak interactions. [Wu experiment]
- Helicity and chirality.V-A weak currents. Pion decay.
- Helicity of the neutrino.[Goldhaber experiment]
- Weak charged currents in quarks and the Cabibbo angle.
- Charm and GIM mechanism. Absence of Flavor Changing Neutral Currents (FCNC)
- CKM matrix and quark mixing. Particle-antiparticle conjugation violation (CP)
- Feynman diagrams for weak processes.

Bibliografia e materiale didattico

Complete textbooks:

- Bettini - Introduction to Elementary Particle Physics - Cambridge U.P. (2012),
- Griffiths - Introduction to elementary particles - Wiley (2008),
- D.H. Perkins - Introduction to High Energy Physics -- Cambridge U.P. (2000),
- Thomson, Modern Particle Physics, Cambridge U.P. (2013).
- E. Peskin, Concepts of Elementary Particle Phsyics, Oxford U.P. (2018)

Further reading:

- H.J. Lipkin, Lie Groups for Pedestrians, Dover (2002)
- Cahn, Goldhaber - The experimental foundations of Particle Physics - Cambridge U.P. (2009).
- M.S. Sozzi - Discrete symmetries and CP Violation - Oxford G.T. (2008).
- Povh, Rith, Scholz, Zetsche - Particles and nuclei - Springer 6-th Ed. (2008).
- Hagedorn, Relativistic Kinematics

On the interactions of the radiation with matter and particle detectors:

- Green - The physics of particle detectors - Cambridge U.P. (2000),
- Grupen - Particle detectors - Cambridge U.P. (1996),
- W.R. Leo -Techniques for nuclear and particle physics experiments - Springer-Verlag (1994).
- J.D. Jackson - Classical Electrodynamics - Wiley (1998),
- Ferbel (ed.) - Experimental techniques in HEP - Addison Wesley (1987),
- Kleinknecht - Detectors for particle radiation - Cambridge U.P. (1998).

Essential general reference:

- Particle Data Group - Review of particle physics – pdg.lbl.gov

Modalità d'esame

L'esame finale è strutturato con una prova scritta ed una prova orale.

Pagina web del corso

https://elearning.df.unipi.it/course/view.php?id=312

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