UNIVERSITÀ DEGLI STUDI DI MILANO

REGISTRO DELLE ATTIVITA' DIDATTICHE

Dati Anagrafici

STEFANO FORTE

Data di Nascita: 21/06/1961 - **Codice Fiscale:** FRTSFN61H21F205Q

Ruolo: I FASCIA

FIS/02

DIPARTIMENTO DI FISICA

Dati dell'insegnamento

Anno Accademico: 2018/2019 - **Stato del registro:** CHIUSO

Data di chiusura: 03/06/2019

Corso di Studio: FISICA (Classe LM-17)

Insegnamento: Fisica Teorica 1

Forme Didattiche e Ore assegnate:

Lezioni (42.0 ore)

Riepilogo attività

Forma didattica	Ore registrate
Lezioni	42.0

Dettaglio attività

Data	Ora Inizio	Ore	Aula	Sede	Forma didattica	Argomento
04/03/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	Introduction to the course. Quantum field theory. Need to introduce QFT in order to reconcile quantum mechanics with relativity: two options. Historical origin of QFT: quantum electrodynamics. The crisis of QED: renormalization and the proliferation of interactions. The Wilsonian renormalization group. Dimensional analysis and fundamental interactions. Renormalizable and nonrenormalizable interactions. The paradigm of renormalizability. Subjects to be covered in this course. Textbook, teaching assistant, final exam.
06/03/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	Coupled harmonic oscillators: normal coordinates and solutions of the dynamics. Infinitely many coupled oscillators on a line. Continuum limit: Young's modulus. Dimensional analysis. The classical scalar field Lagrangian. The Euler-Lagrange field equations from a variational principle. Canonical (Hamiltonian) formalism for fields. Equations of motion and their solution for the scalar field: planes waves, group velocity, phase velocity. Relativistic case.
11/03/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	"Massive" scalar field. Phase velocity and group velocity. Normal coordinates for the scalar field: plane waves. Decoupling of the Lagrangian. Solutions to the quations of motion. The Lorentz and Poincare groups. Commutation relations. Boost, rotations, translations. The Lorentz group as the product of two rotation groups. Rotation content of Lorentz representations. Construction of Lorentz representations from rotation representations.
13/03/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	Representation of the Lorentz and Poincare group on (classical) fields. Translation and the scalar condition. Representation of symmetry group on Hilbert spaces: unitarity. Classification of representations: Schur's lemma and Casimir operators. Application to the Poincare group: total momentum and the Pauli-Lubanski vector. Interpretation of the eigenvalues: mass and spin. Physical interpretation: the method of induced representations. Massless case: spin states and helicity states. Noether's theorem. Derivation in point mechanics and in classical field theory.
18/03/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	Review of the derivation of Noether's theorem in field theory.; interpretation of individual terms. Conserved current and conserved charge: continuity equation. Internal symmetries: algebra of conserved charges and symmetry algebra. Translations: construction of the energy-momentum tensor. Hamiltonian density and momentum density Symmetrization of the energy-momentum tensor through addition of the gradient of a prepotential. Lorentz transformations: construction of the general expression of the conserved tensor. Orbital angular momentum and spin. Rotations: explicit expression of the orbital angular momentum. Spin and Pauli matrices.
20/03/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	Summary of orbital angular momentum and spin generators. Boosts: the center of mass theorem. Explicit construction of the prepotential that symmetrizes the energy-momentum tensor. Quantization of the real massive scalar field. Construction of the Lagrangian. Dimensional analysis: "free " theory and interactions. Classical equations of motion and normal coordinates. Energy and momentum. Canonical quantization of the creation and annihilation operators. Normalization of the creation and annihilation operators and of the commutators. The field operator as Heisenberg operator. The hamiltonian in terms of creation and annihilation operators.
25/03/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	Zero point energy and its meaning: the Casimir effect. Momentum operator. One particle states as eigenstates of momentum and spin. Fock space. Normalization of physical states. The canonical field and momentum and their commutation relations. Action of the momentum operator on the canonical field. Complex scalar field. Internal symmetry and conserved current and charge. Energy-momentum tensor. Normal coordinates. Action of the energy, momentum and charge on one-particle states. Particles and antiparticles. The Maxwell field. Lagrangian and (classical) Maxwell equations. Conservation of the source current. Gauge invariance. Counting of degrees of freedom at the classical level. Transverse polarizations. Normal coordinates. Quantization. Energy-momentum tensor. Expression of energy, momentum and spin in terms of creation and annihilation operators.

27/03/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	The Dirac field. Gamma matrices, Clifford algebra, Lorentz generators. Gamma matrices in d dimensions: three-dimensional example. Weyl representation of the gamma matrices: rotations, boosts and SU(2) content. Hermiticity properties of the gamma matrices. The bar spinor and its transformation properties. Transformation of the gamma matrices upn the adjoint action of the Lorentz group. Minimial scalar Lagrangian for the Dirac field. Equations of motion. Energy momentum tensor, energy and momentum. Conserved U(1) current. Solutions to the Dirac equation. Plane waves, u and v spinors. Gamma5 matrix and spin .
01/04/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	Massless solutions to the Dirac equation: helicity and chirality. Expression of the Hamiltonian in terms of creation and annihilation operators. Quantization with anticommutators and energy of the vacuum. Energy, charge and the "Dirac sea". Pauli principle and Fermi statistics. Canonical formalism for Fermi fields. Interactions and transition amplitudes. General expression for amplitudes and S-matrix elements. Time-evolution operator and path ordering. Interaction picture: relation to the Schroedinger picture and time evolution of states. Amplitudes in the interaction picture. Vacuum-to-vacuum transition amplitude and the cluster decomposition principle.
03/04/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	Summary of the general expression for matrix elements. Amplitudes and Green functions. The path integral approach to quantum physics. Wave function and propagator. Properties of the propagator: associativity. Evaluation of the propagator for an infinitesimal evolution. Lagrangian expression for the propagator. Composition of infintiesimal evolutions and sum over paths. The Feynman path integral. Semiclassical limit and dominanice of the minimum action. Path integral and Schroedinger equation: the pathnintegral as a wave function. Hamiltonian and Lagrangian expressions of the path integral. The path integral from quantum mechanics to field theory.
08/04/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	Summary of the properties of the path integral in quantum mechanics: associativity, the PI as the wave function, T-ordered matrix elements from the PI. The path integral in quantum field theory. Computation of expectation values of the field (Green functions) from the path integral: sources and the generating functional. Vacuum expectation values: the convergence factor. The path integral for a free theory as an infinite-dimensional Gaussian integral. Normal coordinates and the momentum representation. Computation of the multidimensional Gaussian integral: eigenvalues of the quadratic operator. Functional determinant. Explicit expression of the generating functional in terms of sources.
10/04/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	Summary of the expression of Green functions in terms of a generating functional for a free theory. Interacting theory: potential and functional derivatives of the free-field generating functional. The two-point Green function. Hamiltonian computation. Non-covariant and covariant expression: equivalence. The two-point function as a Green function: the Feynman half-advanced half-retarded propagator. Functional computation: functional differentiation of the generating functional. The kinetic operator and its inverse. The case of vector fields: non-invertibility of the kinetic operator. Explicit expression of the propagator.
15/04/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	The path integral for fermions. Grassmann numbers. Functions of Grassmann numbers. Derivatives and integrals of functions of Grassmann numbers. Complex Grassmann numbers. Gaussian integrals in one dimension and in n dimensions. The path integral and the generating functional for fermion fields. Two-point function for Fermi fields: the Dirac propagator. Interacting fields. Phi^4 and QED Lagrangians. Dimensionality of the fields. Computation at lowest nontrivial order of the photon-electron-positron transition. Expansion of the field, creation and annihilation operators.
17/04/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	In- and outgoing particles: sules for the vertex. The reduction formula: the need to relate interaction picture and heisenberg picture. Definition of the creation and annihilation operators. The Wronskian. Time dependence of the creation and annihilation operators. S-matrix elements. Extraction of particles one at a time. Integration of the time dependence Integration by parts and covariant expression. Iteration of the procedure and time ordering. Final state particles. General reduction formula. Expression in terms of inverse propagators.
29/04/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	Position-space and momentum-space forms of the reduction formula. Inversion of the reduction formula: the amplitude as a residue of a multiple pole in the Green function. Reduction formulae for the Dirac field and for a vector field (photon field). Computation of the photon to electron-positron transition in a Lagrangian formalism. Need to (a) have a propagator on each external leg and (b) remove all sources in order to get a nonvanishing result. Expression of the vertex: lowest order and higher orders. Feynman rules: external particles, propagators and vertices. Symmetry factor. Fermions.

06/05/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	Summary of the Feynman rules. Use of the Feynman rules for the computation of Green functions vs amplitudes: connected diagrams. Normalization by the vacuum-to-vacuum amplitude. Vacuum bubbles. First example of computatio. QED with two species of fermions.: "electron" and "muon" The process e+e-->mu+mu. The Feynman diagram. The amplitude. Square amplitude. Unpolarized case: summing and averaging over polarizations. Sums over Dirac spinors and projectors. The square amplitude as a trace. Traces over gamma matrices. Computation of the squared, spin-averaged amplitude. The m_mu>>m_e limit. Counting of degrees of freedom for a 2->2 process. Number of independent momentum components, conservation laws, and number of independent parameters. Lorentz invariance and independent scalar products. Mandelstam invariants. Relation between Mandelstam invariants and masses. Expression of the amplitude for e+e-->mu+mu- in terms of Mandelstam invariants.
08/05/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	Choice of reference frame. Invariant matrix element in the center-of-mass frame. The cross-section: flux factor and phase space. Intuitive definition of the flux factor: expression in terms of scalars. Computation of the flux factor and of the phase space for e+e-->mu+mu-. Final expression of the cross-section. Total cross-section. The massless limit: total cross-section and dimensional analysis. The angular dependence of the differential cross-section from angular momentum conservation. Introduction to loop computations. The phi^4 theory. Computation of the tree level elastic phi-phi scattering amplitude. One-loop diagrams.
13/05/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	Structure of the one-loop diagrams. Effective vertex and form factor: s- t- and u-channel contributions. Calculation of the generic scalar integral. The method of Feynman parameters: reduction to the integral to a scalar integral. Wick rotation and computation of the Euclidean integral in the most general case. Computation of the form factor with cutoff regularization: explicit expression. Meaning of the coupling: physical coupling. Renormalization: expression of the cross-section and form factor in terms of the physical coupling. Choice of renormalization scheme: the renormalization scale. Arbitrariness of the renormalization scale choice.
15/05/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	Relation between the renormalized coupling and the bare coupling: integration over momentum scales. The bare coupling as coupling at zero length: divergences and the uncertainty principle. Sifferent regularization schemes. Dimensional regularization. Computation of phi-phi scattering to one loop in dimensional regularization. Physical coupling and minimal subtraction. The renormalization scale in dimensionally regularized minimal subtraction.
29/05/2019	10:30	2.0	D	Dipartimento di Fisica	Lezioni	Summary of the relation between renormalized and bare coupling, Multiplicative and additive renormalization: renormalization constants and counterterms. Renormalization at the Lagrangian level and renormalized perturbation theory. The problem of renormalizability: classification of divergences. Degree of divergence in terms of lopps and propagators. relations between number of vertices, external particles and loops from momentum conservation and from the topological structure of diagrams. Expression of the degree of divergence in terms of the number of external particles and of the perturbative order (number of vertices). The case of phi^4 in 4 dimension. Counting of independently divergent diagrams. Dimensional analysis: dimensionality of the field, of the coupling and of an n-particle amplitude. (Feedback on the organization and the contents of the course).
03/06/2019	12:30	2.0	D	Dipartimento di Fisica	Lezioni	Classification of the degree of divergence of diagrams from dimensional analysis. Super-renormalizable, renormalizable, and non-renormalizable theories. Renormalization of the phi^4 theory in four dimension. Counting of primitive divergence. Renormalization conditions and their physical interpretation. Renormalized perturbation theory: Lagrangian, counterterms, Feynman rules. Discrepancies between power counting and actual divergence. The BPHZ proof of renormalizability. Physical interpretation of renormalizability: generation of missing interactions.