Theoretical Particle Physics I

Winter term 24/25

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I. Some basics

1. Quantum mechanics and quantum field theory
2. Natural units
3. Lorentz transformation and Poincaré invariance
4. Dirac equation and its solutions

II. Lagrange densities and Symmetries

1. Lagrange and Hamilton formalism in classical mechanics
2. Transition to continuous systems
3. Noether theorem
4. Lagrange densities

III. Field quantization

1. Motivation
2. Repetition: Heisenberg picture in quantum mechanics
3. Quantising the scalar field
4. Quantising spinor fields
5. Quantisation of spin-1 fields

IV. Perturbation theory

1. Up to now: free theory
2. Interaction terms in the Lagrange density
3. QED as abelian gauge theory
4. Interaction picture
5. Time evolution of states: S matrix
6. Wick theorem
7. Computation of S matrix elements
8. Feynman rules for QED
9. From $\mathcal{L}$ to Feynman rules: a recipe

V. Fundamental processes in QED

1. Cross sections and decay rates
2. $2 \to 2$ processes
3. $|\mathcal{M}|^2$
4. Compton scattering
5. Muon pair production
6. Bhabha scattering
7. Scattering on external fields
8. Elastic electron-proton scattering

VI. Spontaneous symmetry breaking

1. Goldstone model
2. Goldstone theorem
3. Higgs model

VII. Decay rates

1. 2-particle phase space
2. Higgs boson decay
3. 3-particle phase space

VIII. Fermi theory of weak interaction

1. Introduction
2. Muon decay
3. Electron-neutrino scattering
4. Charged pion decay
5. Unitarity and the W boson